Water Power
INTERNATIONAL DEVELOPMENT OF HYDRO-ELECTRIC POWER

KARIBA

lting Electrical and Mechanical Engineers: Messrs. Merz and McLellan

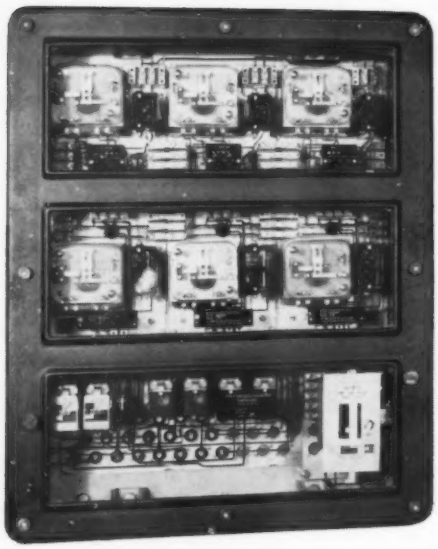
and AEI

Six 100-MW generators for Stage One of the massive hydro-electric project at Kariba, on the Zambesi river, are being supplied by AEI. They are the largest hydro-electric generators in the entire continent of Africa.

AEI

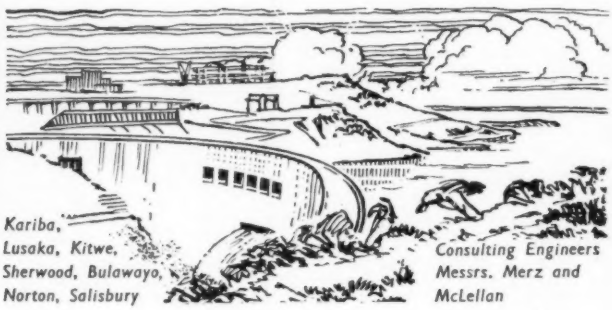
Associated Electrical Industries Limited
Heavy Plant Division
RUGBY, ENGLAND

A5552



KARIBA

330-kV Transmission System Protected by Reyrolle Type-H Distance Protection



Kariba, Lusaka, Kitwe, Sherwood, Bulawayo, Norton, Salisbury

Consulting Engineers Messrs. Merz and McLellan

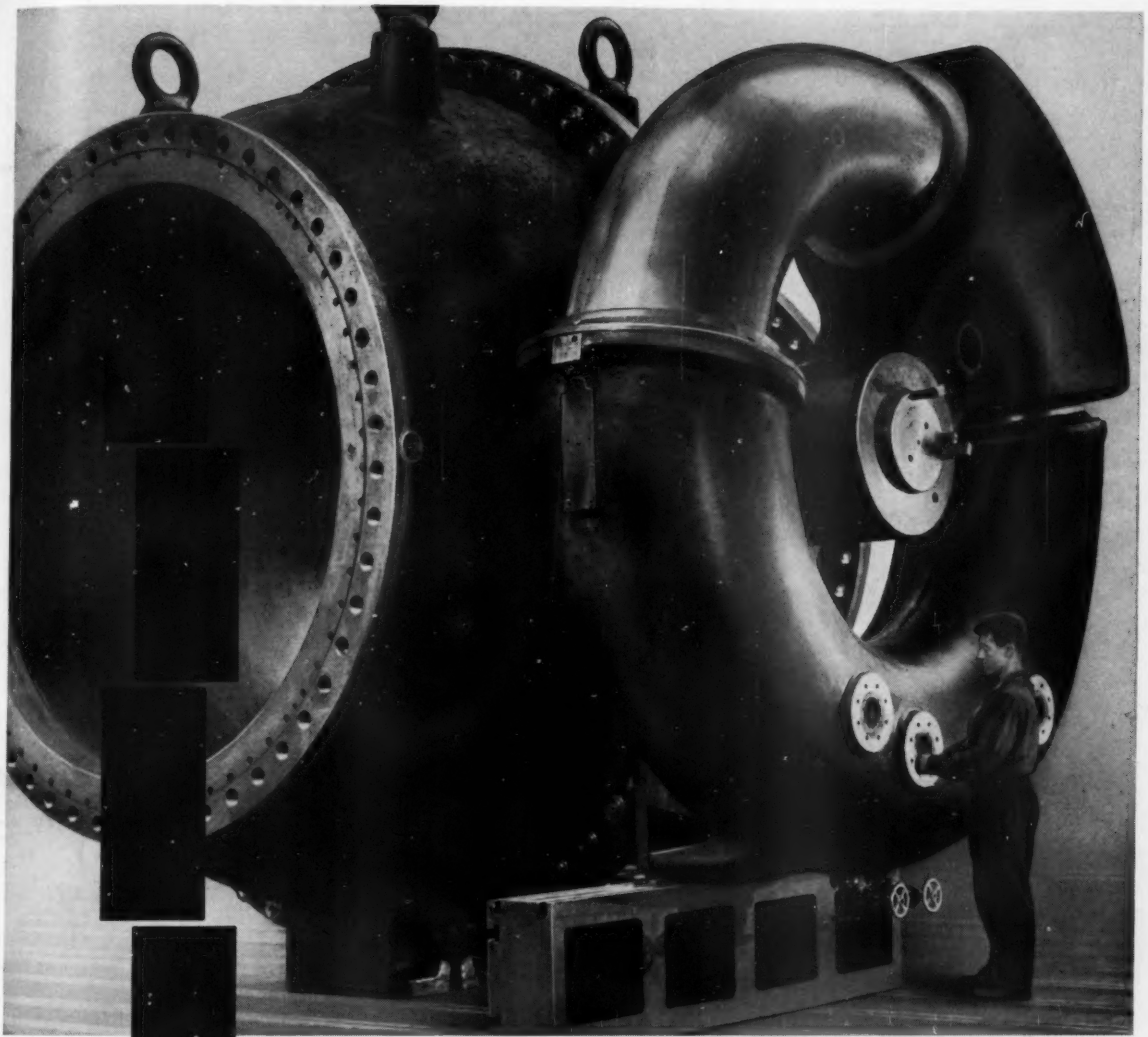
Reyrolle type-H high-performance distance protection incorporates the following important features:

- High speed for all types of fault
- Accurate measurement for exceptionally wide range of source to line impedance
- Negligible over-reach on D.C. transients
- Separate moving-coil elements for earth-faults and phase-faults
- All relay-elements identical and easily removable
- Self-contained design reduces panel wiring
- Built-in phase-selectors for single-phase auto-reclosing if required

Applied to major transmission lines throughout the world

Reyrolle

A. REYROLLE & COMPANY LIMITED - HEBBURN - COUNTY DURHAM - ENGLAND



Assembly of a Spherical Valve
destined for
Le Marinel Power Station
(Belgian Congo)
nominal diameter 2200 mm (87 in.),
working pressure 18 kg/cm² (256 psi),
with patented
Ring-Piston Servomotor

This is the stone
that makes
the tower
stand or fall.
In a Power Station
it is the **Shut-off Valves**
that provide for the safety
of the entire plant
and thereby
make it stand or fall

323

DE ROLL

Shut-off Valves

our speciality

DE ROLL Iron Works, Klus (Switzerland)

BUILDING FOR POWER

Huwood Conveyors are in wide use, not only in Britain but throughout the world—one of their most important applications being in the work of dam building for hydro-electric schemes.

They have been chosen because they offer the highest degree of adaptability to varying sites, the utmost reliability, and the minimum of routine maintenance.

Huwood Conveyors

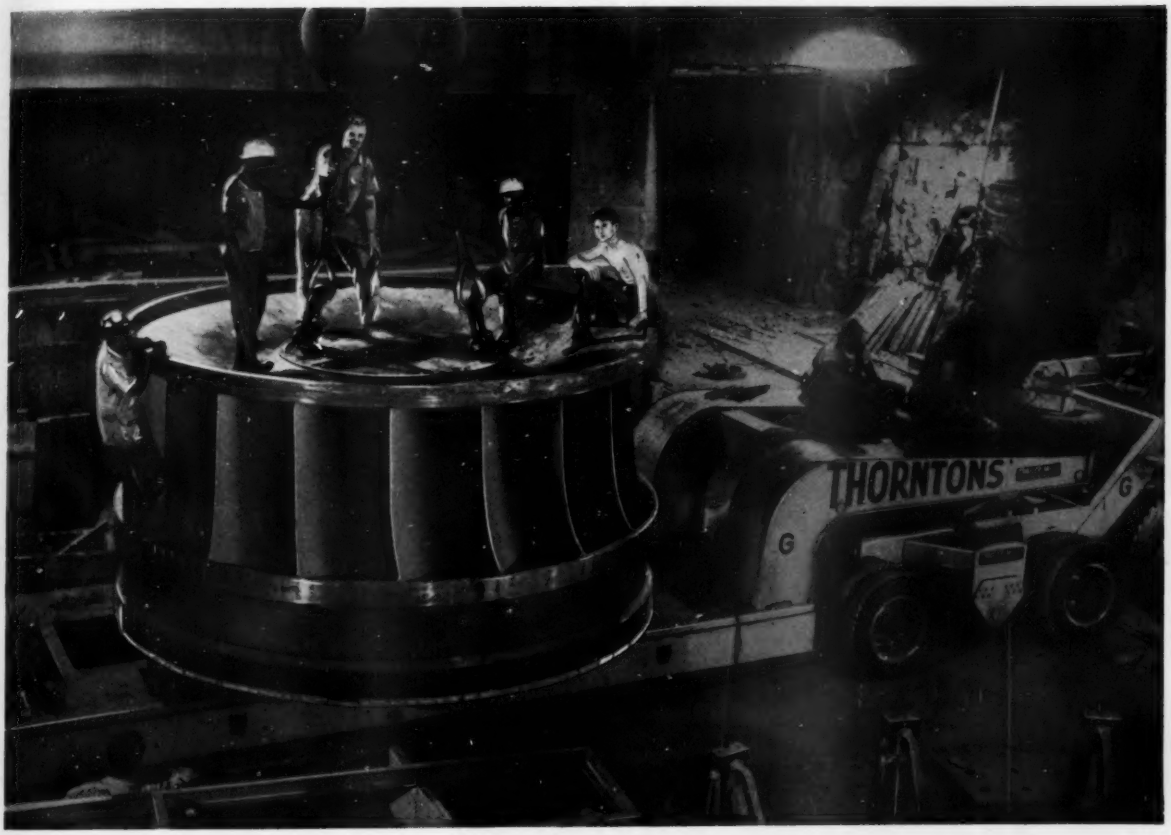
HUGH WOOD & CO. LTD.

Head Office and Factories
GATESHEAD-ON-TYNE, 11
Telegrams: Huwood, Gateshead. Telephone: Low Fell 76081 (5 lines).

Industrial and Export Office
ROYAL LONDON HOUSE, FINSBURY SQUARE, LONDON, E.C.2
Telegrams: Huwood Stock, London. Telephone: Monarch 3273 (4 lines).

KARIBA—a stage completed

Another stage begun



Boving are supplying the six Water Turbines for Kariba, each of 140,000 h.p. Work is keeping pace with schedule and No. 3 turbine is approaching the completion stage.

Merz & McLellan—Electrical and Mechanical Consulting Engineers to the Federal Power Board.

Boving

& CO LIMITED

VILLIERS HOUSE • 41-47 STRAND • LONDON WC2

P.4096

325,000 horsepower in 5 KMW turbines at ASWAN

Five Kaplan Turbines have now been delivered by KMW to the Aswan Power Plant, two of which have already been put into service, while the remaining three will be in commission by the beginning of next year.

Each turbine has an output of 65,000 HP at a normal head of 88.5 feet and a speed of 100 r.p.m. The weight of each complete runner is 135 tons and the runner diameter 19 feet. The runner blades are made of stainless steel.

AB KARLSTADS MEKANISKA WERKSTAD
KARLSTAD - SWEDEN

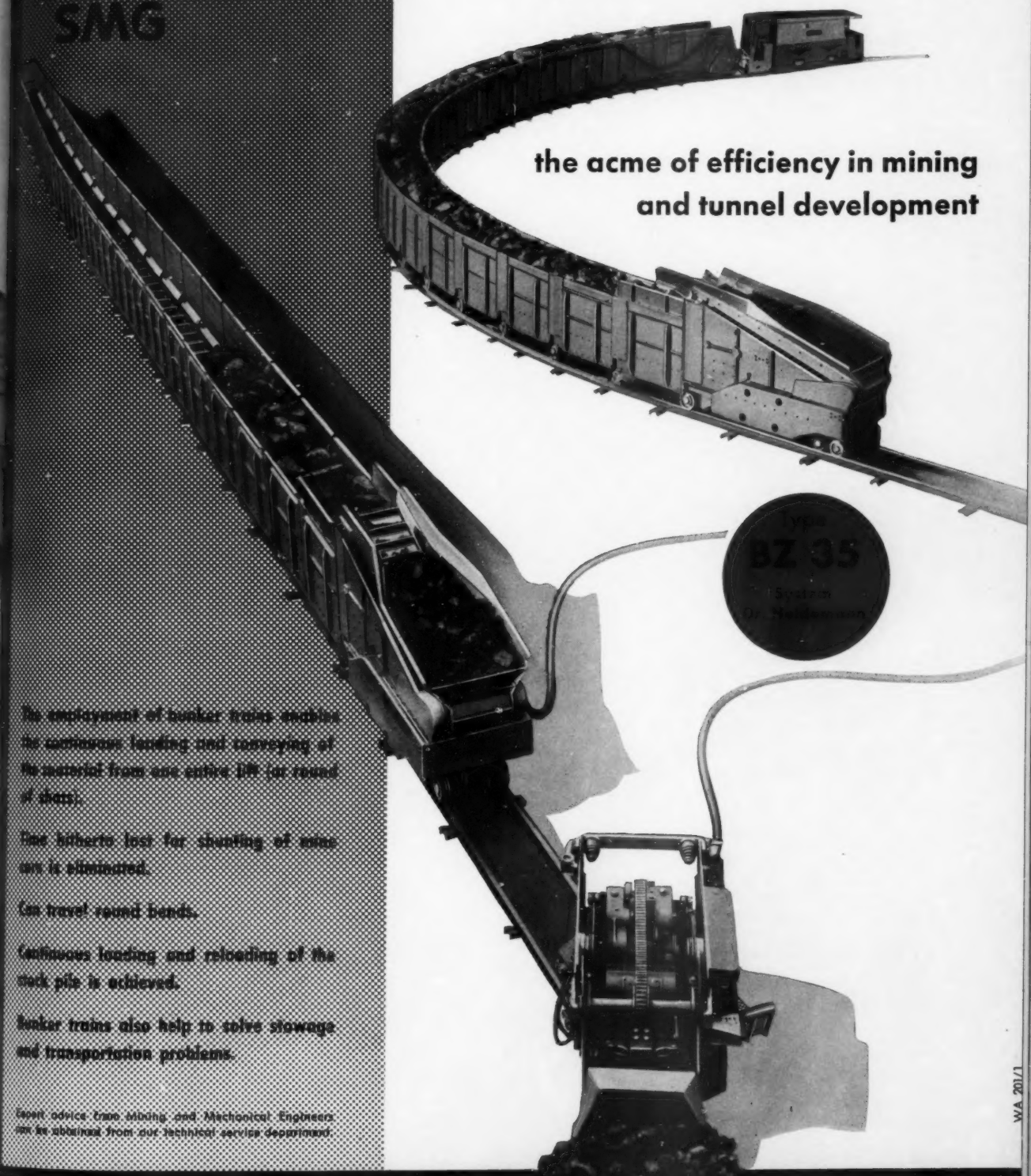
KMW

Representatives in Canada: A. Johnson & Co. (Canada) Ltd.
P.O. Box 56, Montreal 16.

SALZGITTER BUNKER TRAIN

SMG

the acme of efficiency in mining and tunnel development



The employment of bunker trains enables the continuous loading and conveying of the material from one entire lift (or round of shots).

Time hitherto lost for shunting of mine cars is eliminated.

Can travel round bends.

Continuous loading and reloading of the rock pile is achieved.

Bunker trains also help to solve stowage and transportation problems.

Expert advice from Mining and Mechanical Engineers can be obtained from our technical service department.

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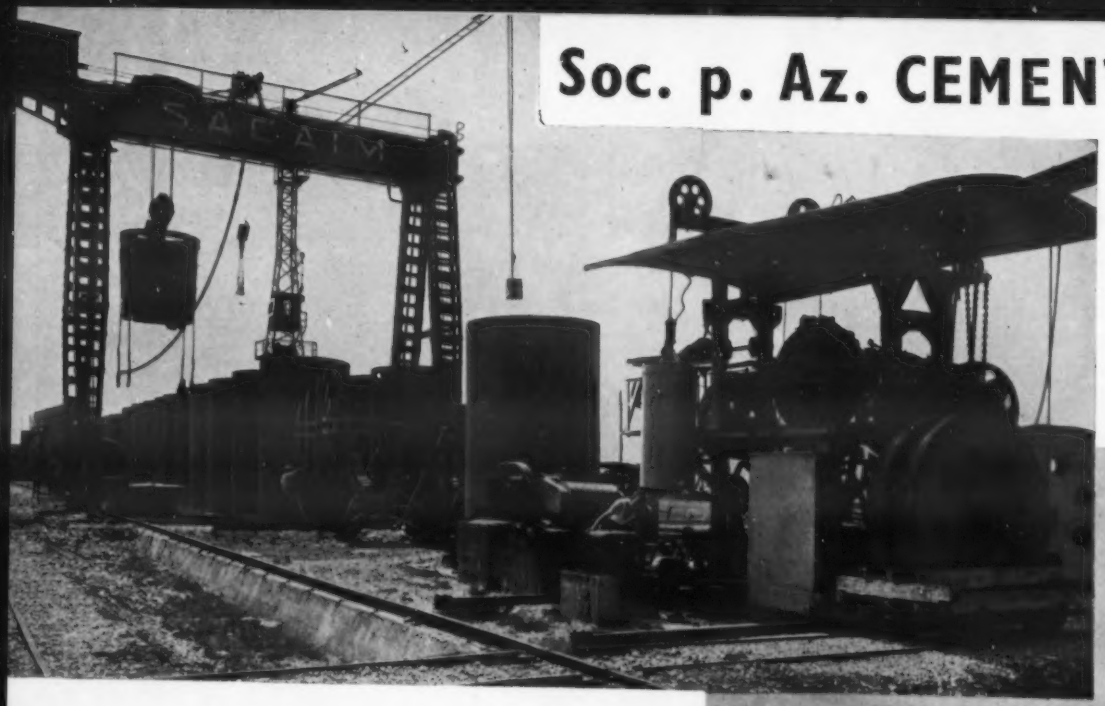
SALZGITTER MASCHINEN AKTIENGESELLSCHAFT

SALZGITTER-BAD (W. Germany)

3441

telex: samag sgtr 0953805

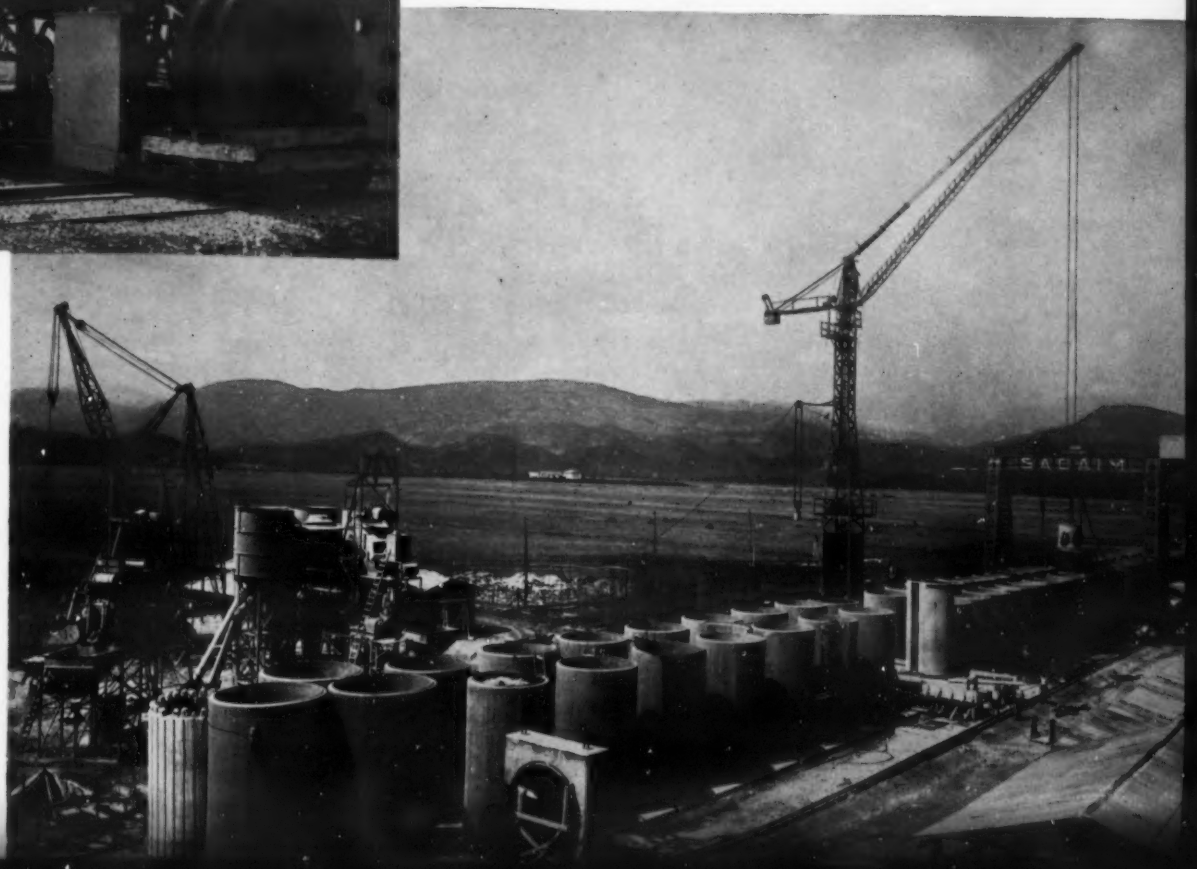
samag



Soc. p. Az. CEMENTI ARMATI Ing. MANTELLI

VENEZIA-Accademia No. 979a · Tel. 85-060

SACAIM

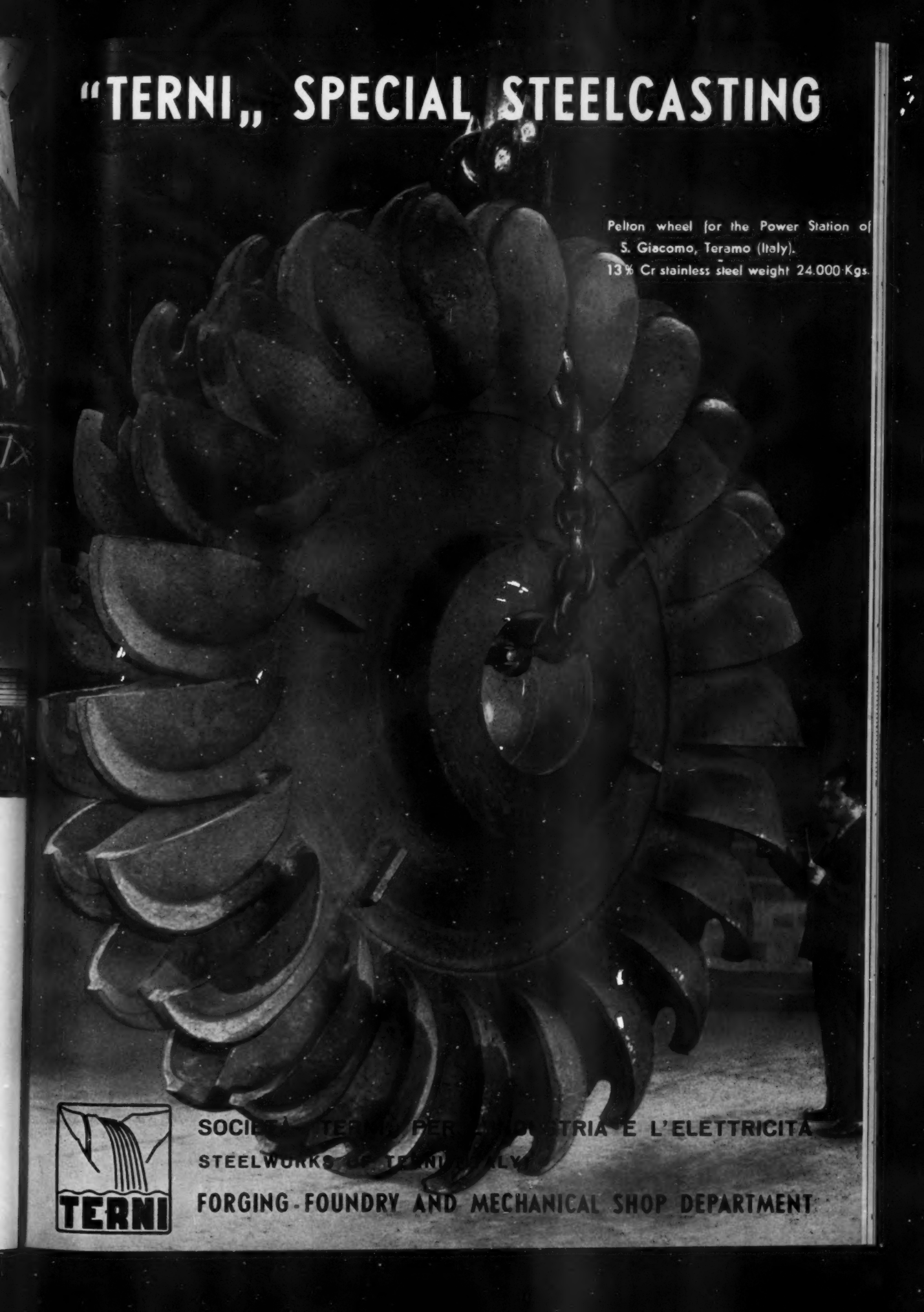


Prestressed reinforced concrete Penstocks (internal diameter 2.60 metres) for the Meduna hydro-electric station of

S.A.I.C.I.

SOC. AGRICOLA INDUSTRIALE PER LA CELLULOSA ITALIANA di MILANO

"TERNI„ SPECIAL STEELCASTING



Pelton wheel for the Power Station of S. Giacomo, Teramo (Italy).
13 % Cr stainless steel weight 24.000 Kgs.

TERNI

SOCIETÀ TERNI PER L'INDUSTRIA E L'ELETTRICITÀ

STEELWORKS OF TERNI - ITALY

FORGING - FOUNDRY AND MECHANICAL SHOP DEPARTMENT

"still giving excellent service after 36 years"—that's the report from Arkansas Power & Light on three Leffel Turbines at Remmel Dam

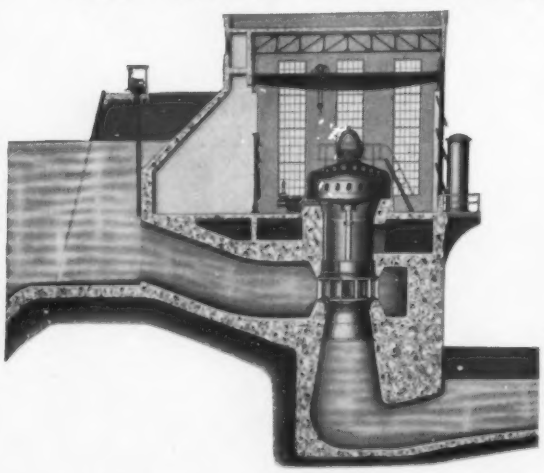


Photo above shows Remmel Dam as it appears today. The dam is located on the Ouachita River near Hot Springs, Arkansas. Seventy-five feet high and 900 feet long at the apex, it creates Lake Catherine, with a total area of 2624 acres. Drawing shows a cross-section of the Remmel Dam power house, unusual in that the turbines are installed at a height of 19' above tail water.

In 1924, three Leffel vertical shaft turbines were installed at the Arkansas Power & Light Company's Remmel Dam hydro-electric station . . . Arkansas's first major hydro-electric facility.

In addition to the three turbines, each rated 5700 H.P. at 120 R.P.M. under a 50 foot net head, Leffel also furnished the outside gate equipment for the Remmel Station.

Arkansas Power & Light's report, after 36 years of operating experience, boils down to "very well pleased with the equipment, which is still operating satisfactorily . . . very little in the way of repairs required during the 36 years."

An unusual case? Not for Leffel. Long life and reliable service are the routine, not the exception for Leffel turbines. That's why satisfied Leffel customers in all parts of the world, like Arkansas Power & Light, will turn to Leffel for help on their next hydro-electric project, whether it be a completely new installation or the rehabilitation or expansion of existing facilities.

You, too, can take advantage, without obligation, of Leffel's nearly a century of experience in designing and building fine hydraulic turbines. Just drop us a line outlining your requirements, or the nature of your water power problem.

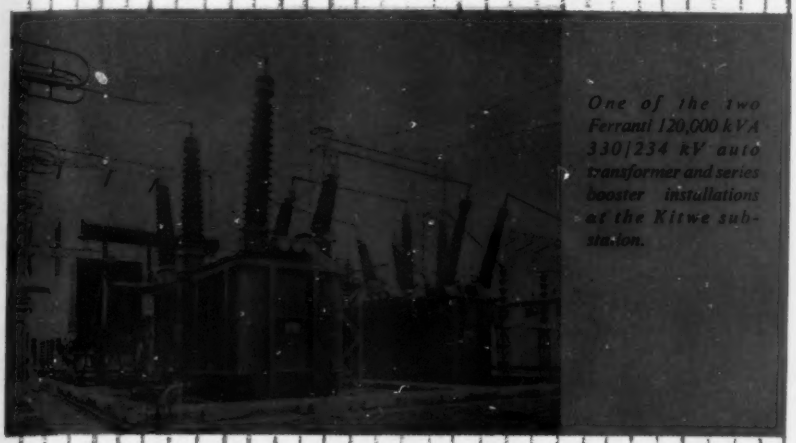
1114-E

FOUNDED IN 1862

THE JAMES LEFFEL & CO.

DEPARTMENT W • SPRINGFIELD, OHIO, U. S. A.

MORE EFFICIENT HYDRAULIC POWER FOR 98 YEARS



One of the two Ferranti 120,000 kVA 330/234 kV auto transformer and series booster installations at the Kitwe sub-station.

FERRANTI at KARIBA

Ferranti Summation Metering Panels for the Kariba Power Station.

The transformers and summation metering panels are for these sites.

TRANSFORMERS

All the sub-station transformers for the Kariba Hydro-Electric Scheme are being supplied by Ferranti Ltd. They comprise two 120,000 kVA, 330/234 kV 3-phase auto transformers with series boosters, eight 60,000 kVA, 330/88kV and four 60,000 kVA, 330/33 kV 3-phase double wound transformers. The transformer installations at Norton, Lusaka and Kitwe are complete. Work at Salisbury, Bulawayo and Sherwood is well advanced.

SUMMATION METERING

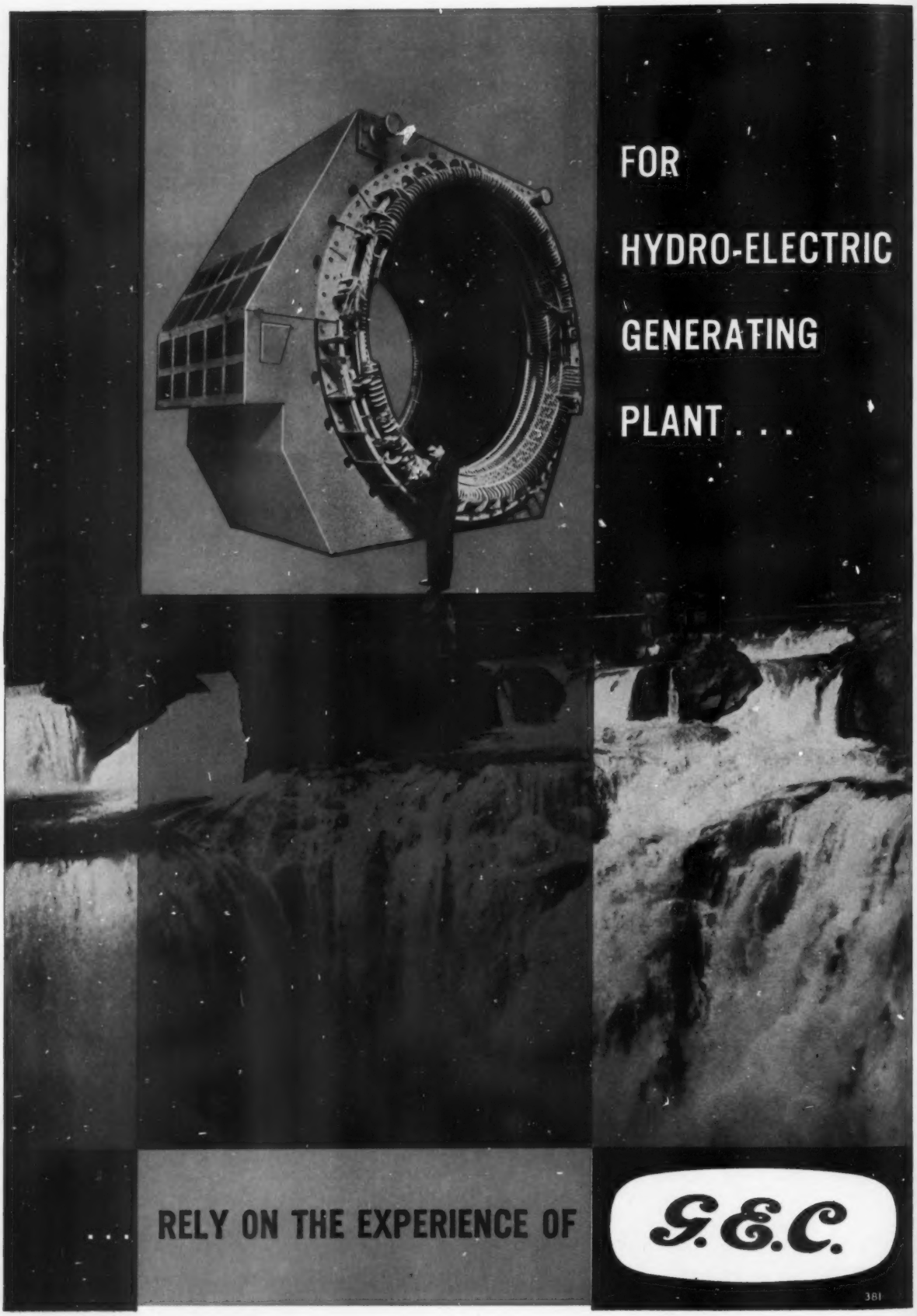
For the same scheme Ferranti Ltd. are supplying Summation Metering Equipment comprising: Precision grade integrating meters, Electro-mechanical summators, Printometer Demand Recorders and Suites of metering cubicles. These equipments will be used to meter six 100 MW generator sets at Kariba Power Station and also the supplies to the Transforming Stations at Kitwe, Norton, Salisbury, Lusaka, Sherwood and Bulawayo.

The consulting electrical and mechanical engineers are Messrs. Merz & McLellan.

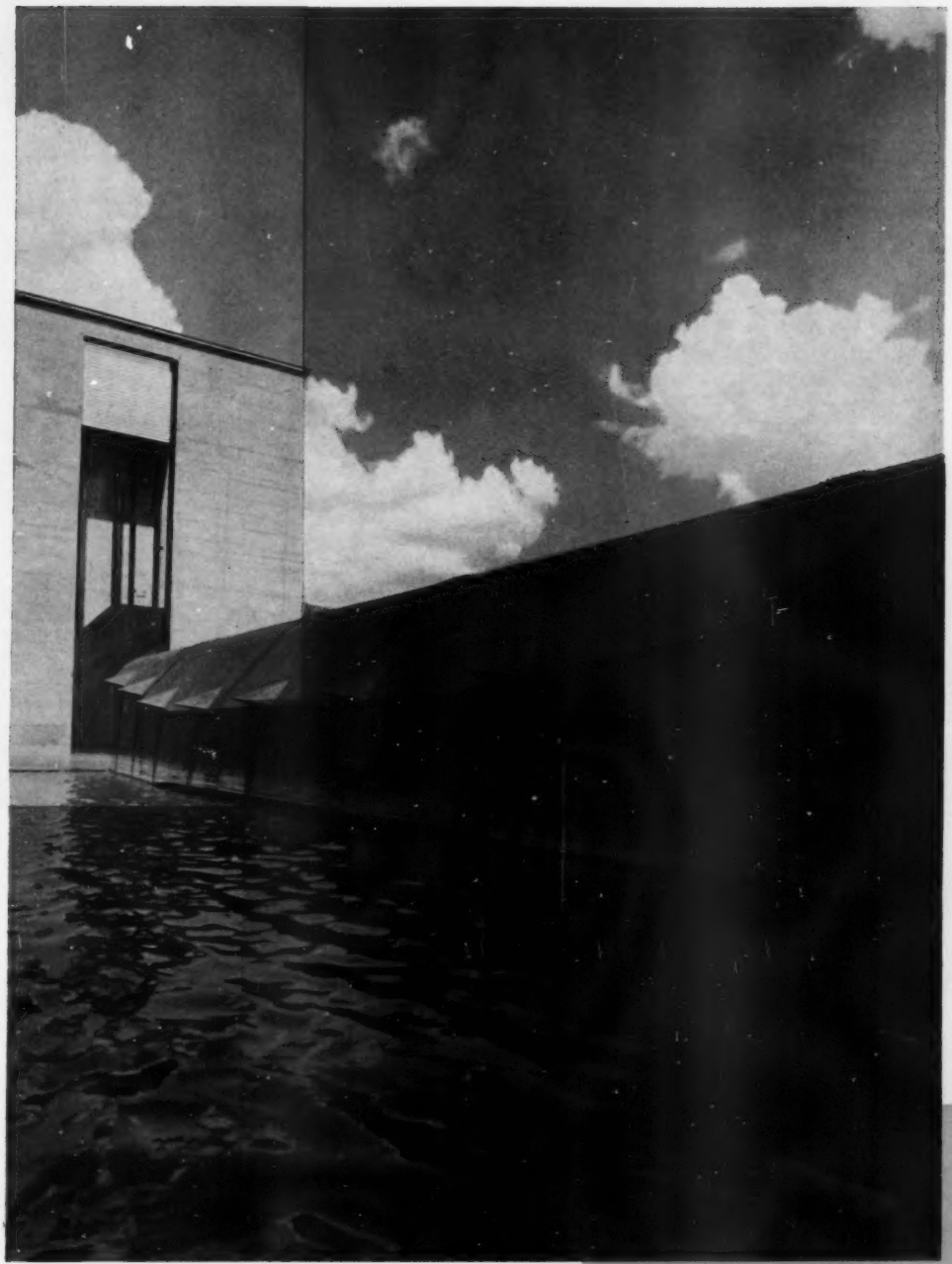
FERRANTI LTD · HOLLINWOOD · LANCS · Tel: FAIlsworth 2000
London Office: KERN HOUSE · 36 KINGSWAY · W.C.2 · Tel: TEMple Bar 6666

Ferranti

FG 307/2


FOR
HYDRO-ELECTRIC
GENERATING
PLANT . . .
. . . RELY ON THE EXPERIENCE OF
G.E.C.
381

M·A·N



In hydro-power plants, minute regulation of the water level is an important feature best achieved by discharging the upstream water over the gate. The M.A.N. submersible sluice gate is particularly suited to that requirement. Illustration shows sluice gate of 30 m clear width and 4.85 m water head supplied for Kitzingen Weir Plant / River Main. Gate was designed to be lowered 1.3 m.

YDRAULIC STRUCTURES

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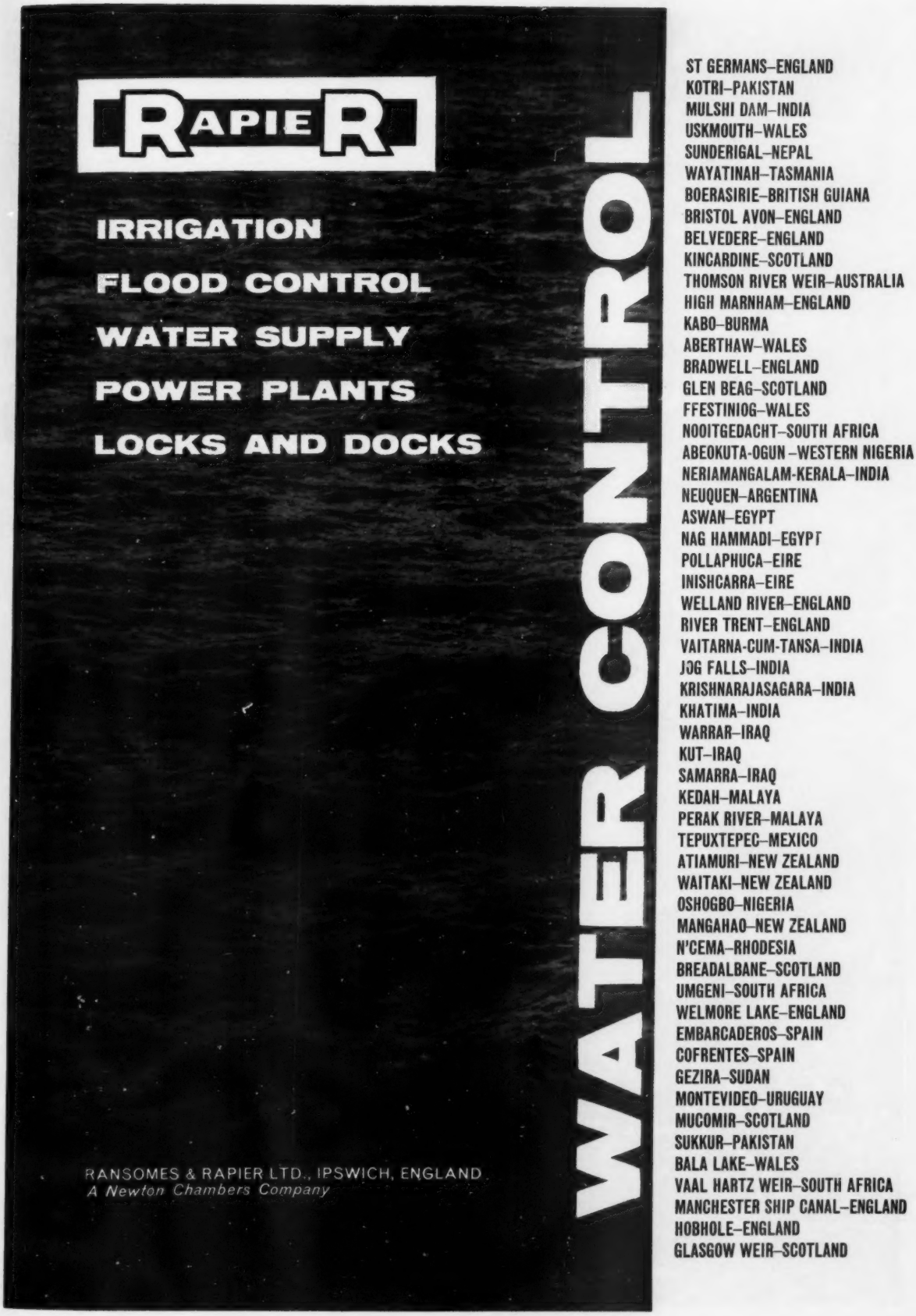
USTAVSBURG/HESSEN (GERMANY) REPRESENTATIVES IN ALL COUNTRIES

105,000 kVA Water-Wheel Generators

makes life comfortable

The comforts of life are the assured gifts of electric power...
Mitsubishi Electric engineers, workers... all perform their important tasks in making life comfortable..... they help in the manufacture of every type of electrical equipment from giant generators and transformers to small home appliances that make life easier. For matchless experience and a distinguished history of achievement, look to the THREE DIAMONDS of the Mitsubishi Brand... the symbol of QUALITY and INTEGRITY.

MITSUBISHI ELECTRIC MANUFACTURING COMPANY
Head Office: Tokyo Building, Marunouchi, Tokyo Cable Address: MELCO TOKYO


RAPIER
IRRIGATION
FLOOD CONTROL
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LOCKS AND DOCKS
WATER CONTROL
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SUNDERIGAL–NEPAL
WAYATINAH–TASMANIA
BOERASIRIE–BRITISH GUIANA
BRISTOL AVON–ENGLAND
BELVEDERE–ENGLAND
KINCARDINE–SCOTLAND
THOMSON RIVER WEIR–AUSTRALIA
HIGH MARNHAM–ENGLAND
KABO–BURMA
ABERTHAW–WALES
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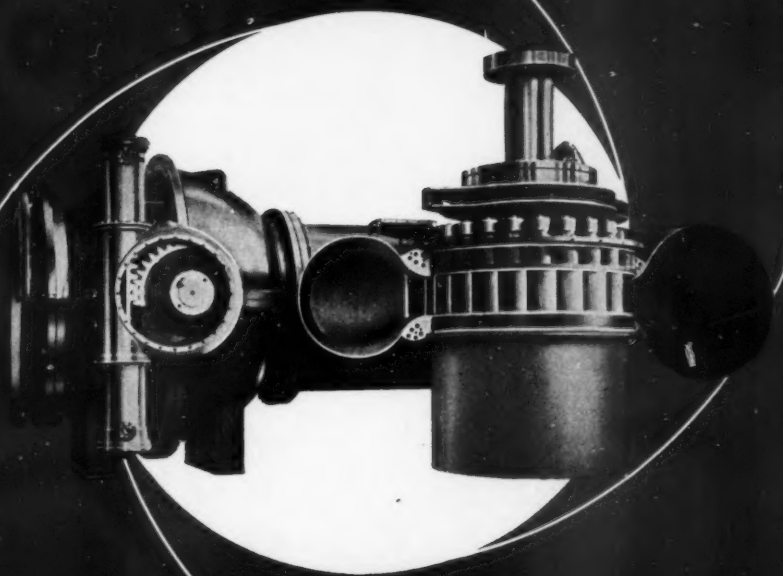
GLEN BEAG–SCOTLAND
FFESTINIOG–WALES
NOOITGEDACHT–SOUTH AFRICA
ABEOKUTA-OGUN–WESTERN NIGERIA
NERIAMANGALAM-KERALA–INDIA
NEUQUEN–ARGENTINA
ASWAN–EGYPT
NAG HAMMADI–EGYPT
POLLAPHUCA–EIRE
INISHCARRA–EIRE
WELLAND RIVER–ENGLAND
RIVER TRENT–ENGLAND
VAITARNA-CUM-TANSA–INDIA
JOG FALLS–INDIA
KRISHNARAJASAGARA–INDIA
KHATIMA–INDIA
WARRAR–IRAQ
KUT–IRAQ
SAMARRA–IRAQ
KEDAH–MALAYA
PERAK RIVER–MALAYA
TEPUXTEPEC–MEXICO
ATIAMURI–NEW ZEALAND
WAITAKI–NEW ZEALAND
OSHOGBO–NIGERIA
MANGAHAO–NEW ZEALAND
N'CEMA–RHODESIA
BREADALBANE–SCOTLAND
UMGENI–SOUTH AFRICA
WELMORE LAKE–ENGLAND
EMBARCADEROS–SPAIN
COFRENTES–SPAIN
GEZIRA–SUDAN
MONTEVIDEO–URUGUAY
MUCOMIR–SCOTLAND
SUKKUR–PAKISTAN
BALA LAKE–WALES
VAAL HARTZ WEIR–SOUTH AFRICA
MANCHESTER SHIP CANAL–ENGLAND
HOBHOLE–ENGLAND
GLASGOW WEIR–SCOTLAND

We design
manufacture and erect

PENSTOCKS

COMPLETE EQUIPMENT
FOR WATER POWER PLANTS



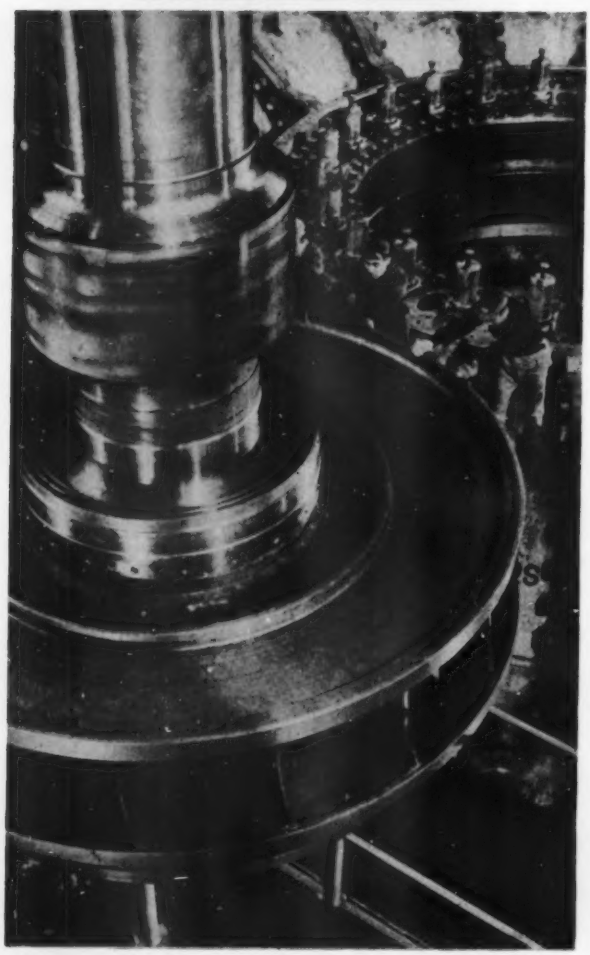
Turbines of the Francis, Kaplan and Pelton type for variable heads and outputs, transformers, generators, outdoor and indoor switch-gear, control rooms, etc.

The world known ŠKODA and CKD trade marks guarantee the first-class technical design and quality of equipment supplied by us. We give integral guarantees for complete deliveries.

TECHNOEXPORT

Foreign Trade Corporation for Exports of Complete Industrial Plants
Su Vladivé nábřeží, Praha 11,
CZECHOSLOVAKIA

Toshiba



Contributing to Your Better Living!

Heavy electric equipment such as Water Turbines, Generators, Power Transformers, and testing equipment for Power Stations, are being shipped out one after another from Toshiba's Tsurumi works.

Shown above is one of the 3 scheduled 133,000 kVA generators—among the largest in the world—to be installed at Okutadami Power Station in central Japan.

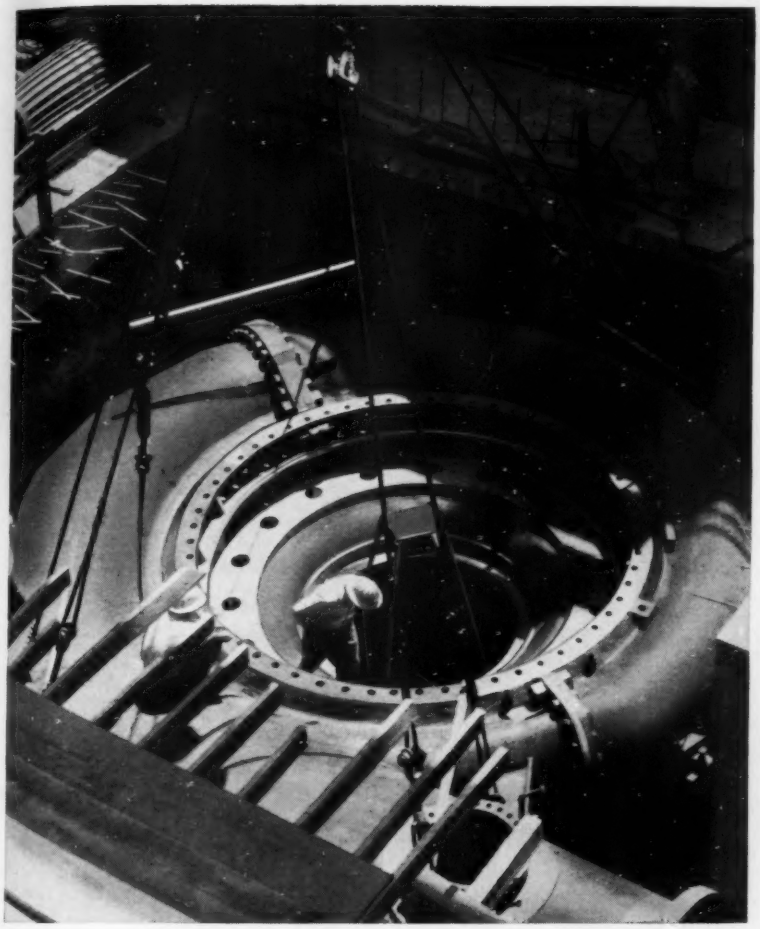
The 137,000 KW Francis turbine, seen at left, to be coupled with this generator is also a Toshiba product. The runner diameter of this turbine is 4,000 mm, and ranks among the biggest in the world.

Similar generators with 58,000 kVA power has been installed at Mazatepec Power Station in Mexico and is now in full operation, Toshiba is also in production for various heavy equipment for many other new projects around the world.

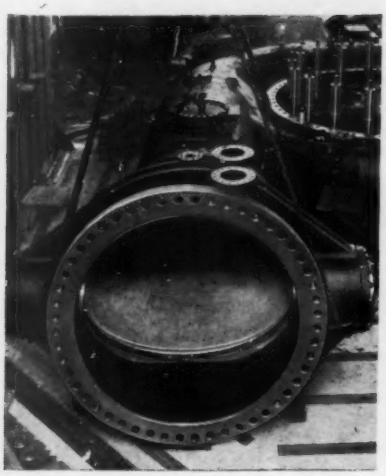
Tokyo Shibaura Electric Co., Ltd.

2 Ginza Nishi 5-Chome, Chuo-ku, Tokyo, Japan
Cable Address: TOSHIBA TOKYO

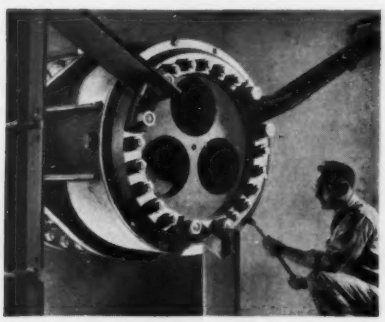
ALLIS-CHALMERS



Spiral case for one of the two A-C Francis turbines at Mammoth Pool (each rated 88,000 hp under 950-ft head at 360 rpm).



Butterfly-type turbine inlet valves—designed for minimum head loss, are bolted directly to 69 inch diameter spiral case inlet flange.



HOWELL-BUNGER valve for pressure relief — one of two 36-inch Allis-Chalmers pressure-regulator valves at Mammoth Pool, in operation under heads exceeding 1000 feet.

Peaking capacity using high-head hydro

...boosts coast utility hydro past the million-kw mark

Two Allis-Chalmers hydraulic turbines installed by Southern California Edison Company at the new Mammoth Pool project operate under a maximum gross head of 1100 feet. After careful consideration of the relative merits of Francis and impulse-type turbines, the Francis type was selected for this high-head installation. Operation of these units as "spinning reserve" required special care in design and manufacture to minimize leakage losses.

Corrosion-resistant wearing plates and gates are precision machined to permit total gate end clearances at assembly of minus nothing to plus 3/1000 of an inch.

Cooling water is piped to the runner seal rings and a complete tailwater depressing system was included by A-C. To facilitate 10-second load rejection and maintenance of minimum downstream flows, A-C supplied two *Howell-Bunger*, free-discharge type, pressure-regulating valves. Two special high head 90-inch butterfly-type inlet valves are provided with corrosion-resistant seals and seat rings adjustable from the outside. A 60-inch *Howell-Bunger* valve and a 72-inch butterfly guard valve are in the reservoir dam outlet works for water release when required.

Look to Allis-Chalmers for engineering, design and manufacture of hydraulic turbines and accessories. *Contact your local A-C office for information or write* **Allis-Chalmers,** *Hydraulic Division, York, Pa.* A-1333

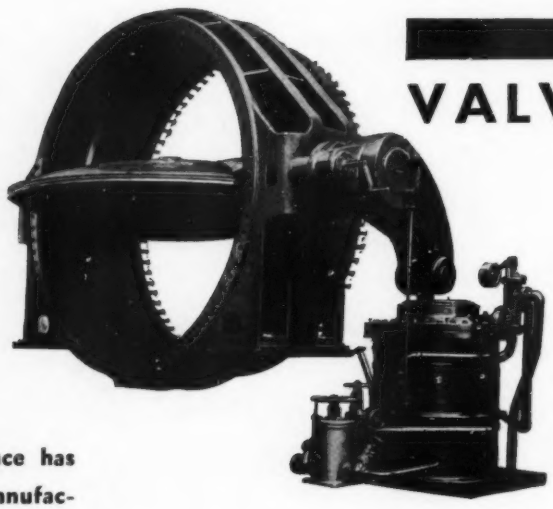
Howell-Bunger is an Allis-Chalmers trademark.

Outside United States contact Allis-Chalmers International, or in Canada, Canadian Allis-Chalmers

GLENFIELD VALVES

for Turbine Inlets

BUTTERFLY VALVES



Glenfield Butterfly Valves are in service for turbine isolation duty in many of the world's hydro-electric schemes.

Over the years a wealth of experience has been accumulated in the design and manufacture of this kind of equipment, and numerous units have been produced in a great variety of sizes for a wide range of operating conditions.

Glenfield

GLENFIELD & KENNEDY LIMITED KILMARNOCK

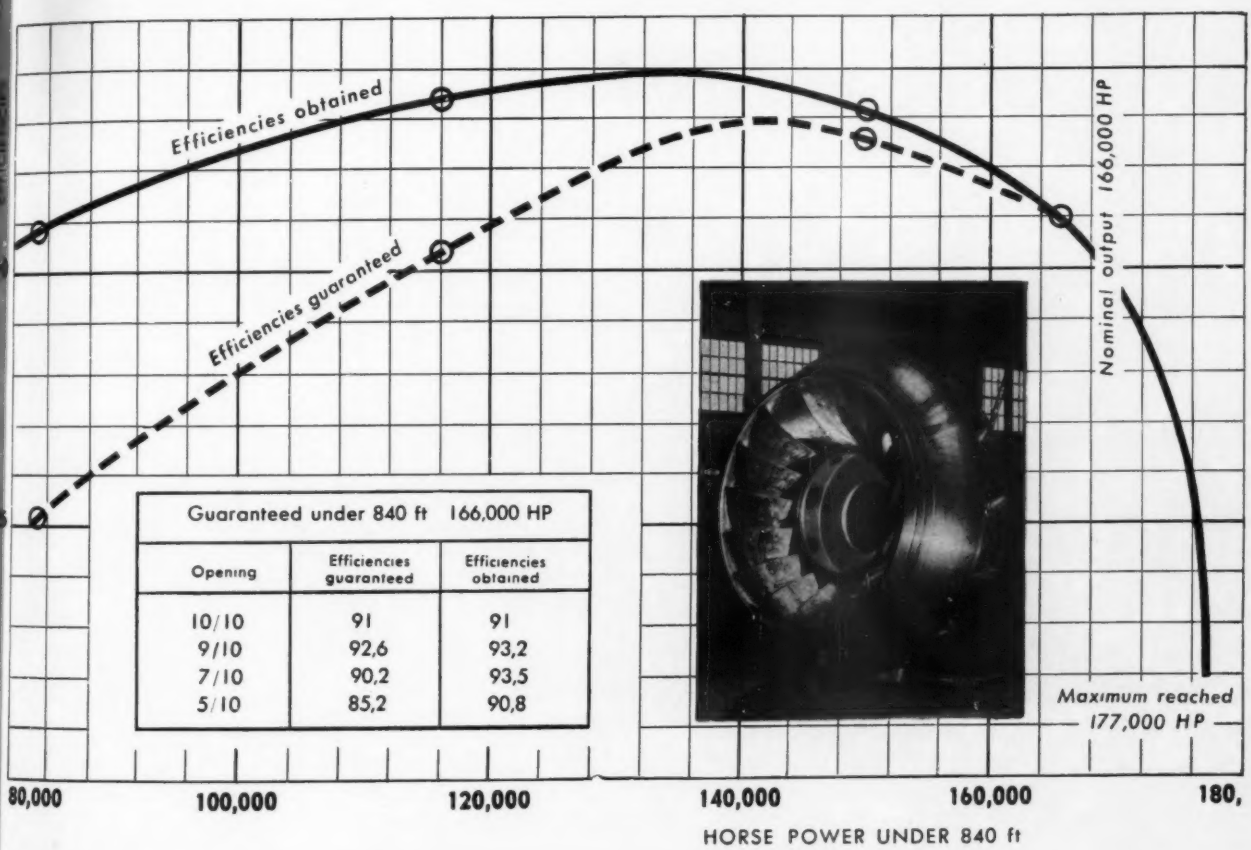
Head Office & Works
KILMARNOCK,
SCOTLAND.

The sound qualities of Neyrpic turbines were again confirmed at Bersimis when the efficiencies of units 5 to 8 exceeded the guaranteed values

BERSIMIS

C A N A D A

Bersimis Neyrpic turbines exceed expectations !



Guaranteed under 840 ft 166,000 HP		
Opening	Efficiencies guaranteed	Efficiencies obtained
10/10	91	91
9/10	92,6	93,2
7/10	90,2	93,5
5/10	85,2	90,8

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Avenue de Beauvert
Téléphone : 44-55-30

NEYRPIC

PARIS XVI
2-10, Rue Bellini
Téléphone : PAS. 51-09

LOCH GIORRA DAM

The new Giorra Dam shown below was built by Edmund Nuttall, Sons & Co. (London) Ltd., for the North of Scotland Hydro-Electric Board. The dam, which is 1,450 feet long and 100 feet high, stands at the eastern end of Loch Giorra and forms an important part of the Breadalbane Power Scheme.

Authority: North of Scotland Hydro-Electric Board
Consulting Engineers: James Williamson & Partners

EDMUND NUTTALL

CIVIL ENGINEERING CONTRACTORS

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h = 860 ft.

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G. TORNO & C. SOC. P. AZ.
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ENGINEERING CONTRACTORS
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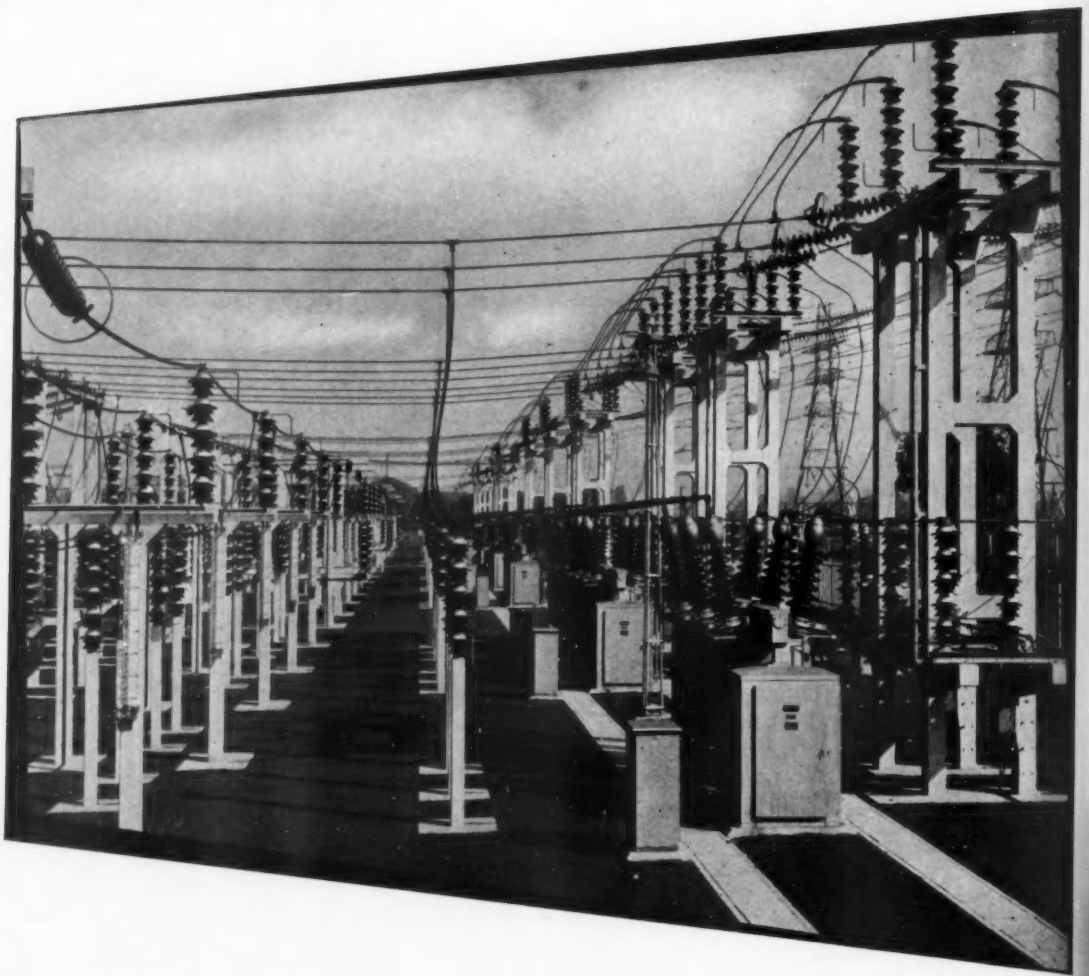
7 VIA ALBRICCI – MILANO – ITALY

DOULTON INSULATORS

designed for uninterrupted service



The Central Electricity Generating Board's Supergrid Substation at Penn, near Wolverhampton, has 132 kV isolators and busbars for which Doulton's supplied the post type insulators.

This Substation is a key point on the gigantic 275 kV "Ring Main" now being built round Birmingham and the Black Country.

Doulton's range of heavy duty posts also includes designs up to 400 kV.

DOULTON INDUSTRIAL PORCELAINS LIMITED

ROYAL DOULTON POTTERIES
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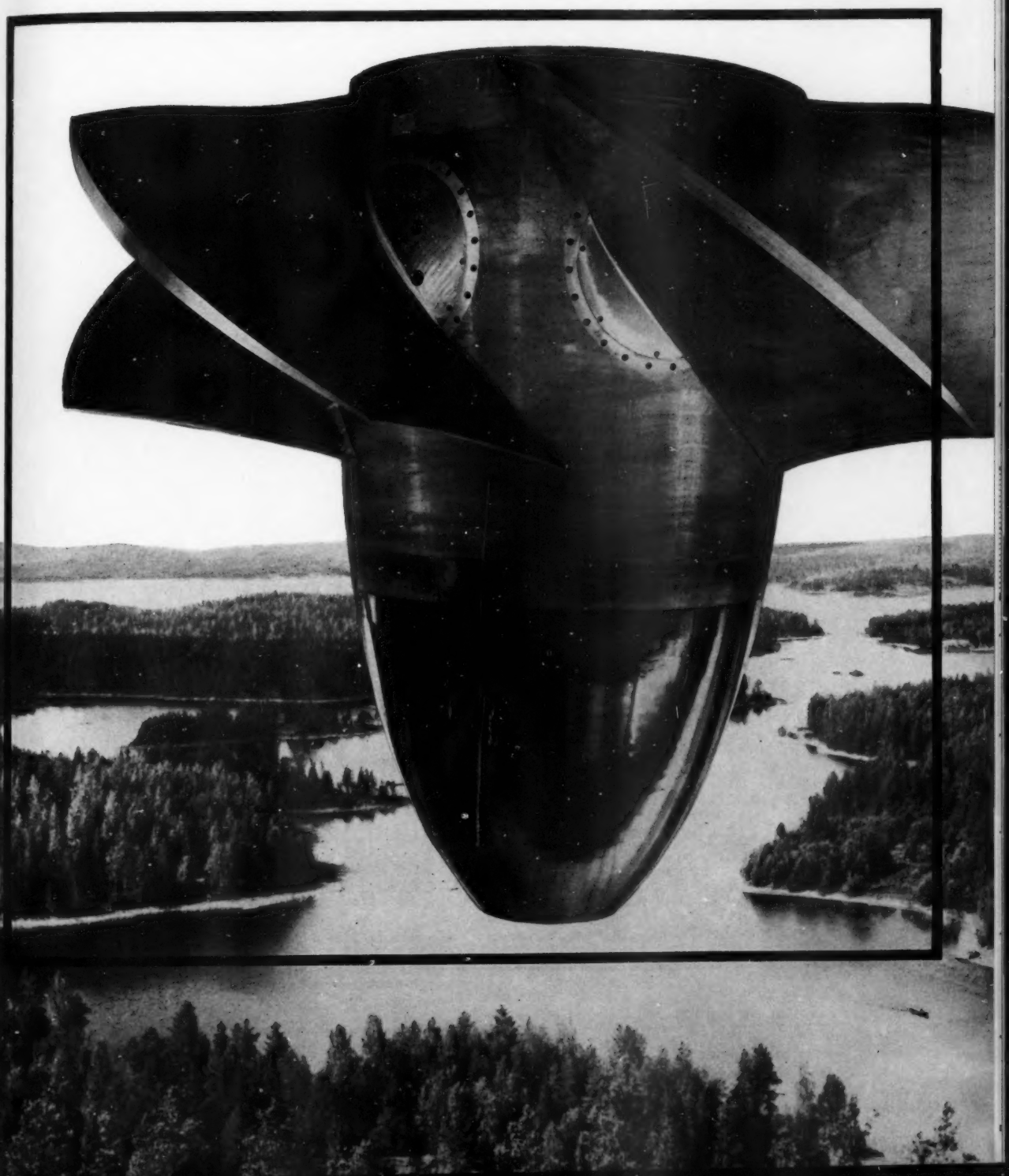
ESCHER WYSS
turbines near the Arctic Circle

The 83,400 HP Kaplan turbines for Pirttikoski Power Station in Finland represent another example of our activities as suppliers of Hydraulic Installations throughout the world. These units are designed to operate at 115.4 rpm under 29 metres head with 232 cub. m/sec. developing unit outputs of 83,400 HP.

Escher Wyss Ltd. Zurich/Switzerland



SWEDISH LADDER

New drifting technique doubles drill-crew output

Controlled feed · guided collaring · mechanical retraction— so one man can operate two rigs

NORTHERN SWEDEN has been the proving ground of a revolutionary rock drilling method which has opened the way to a completely new conception of drill-crew output. Known as the Swedish Ladder Drilling Method, this new technique has been employed on hydro-electric projects at Korsselbränna and Stalon where drilling platforms with 16 rock drills operated by 8-man drill crews have been used.

Atlas Copco drills mounted on retractable pusher legs* are rested in cradles running horizontally in "ladders". Contractors and drill crews have found that these rigs, cheaply and simply constructed, offer the following advantages:

INCREASED PENETRATION—full feed power is ensured by the ideal horizontal feeding position of the pusher leg.

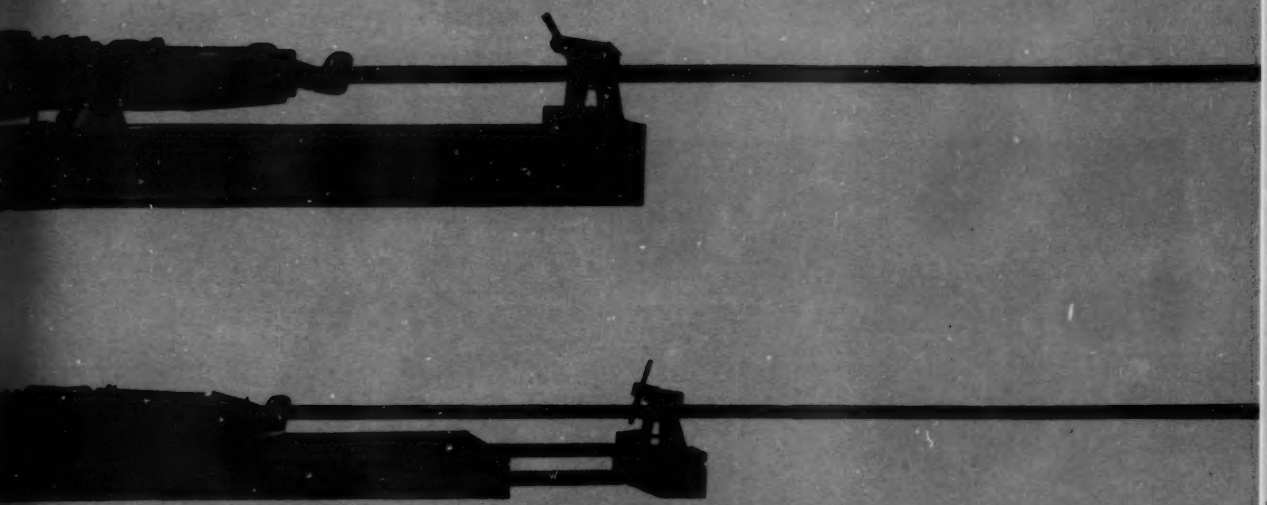
HIGHER OUTPUT PER MAN/HOUR—due to greater penetration and the fact that *one man handles two drills.*

REDUCED CREW FATIGUE—collaring is made simple as operators need not hold the drills. Drill steels are mechanically withdrawn from holes using the retractable pusher leg.

FEWER DRILL STEEL CHANGES—long steels can be used from the start. For greater durability 1″ Sandvik Coromant integral steels are used.

GREATER DRILLING ACCURACY—thanks to the fixed ladder base and pre-positioning of drills for pattern drilling.

DRILLING METHOD



DRAMATIC RESULTS OF LADDER DRILL TESTS

The figures show the dramatic increase in drilling achieved by ladder rigs in a 60 sq.m. tunnel at Stalon driven in hard-drilled quartzite. Gross effect refers to the mean value for the whole drilling period, including collaring, changing steels and the usual routine delays. *Note that the gross effect is exactly doubled.*

GROSS EFFECTS

19.5 metres/man-hour Conventional drilling with *one rock drill*

39.0 metres/man-hour Ladder drilling with *two drills*

AVAILABLE FROM ATLAS COPCO

The Swedish Ladder Drilling Method was originally introduced by Widmark and Platzer, one of Sweden's leading contracting companies, and has been further developed by them and by the Swedish State Power Board. Specially evolved with Atlas Copco trigger-operated retractable pusher legs*, this method and equipment has been exhaustively tested and proved under tough Swedish drilling conditions. There are Atlas Copco companies or agents in ninety countries and details of the new equipment are readily available from them or from the address below. Wherever you are, the international Atlas Copco group offers expert advice on the selection of equipment and a complete after-sales service.

WRITE FOR THE BOOKLET! The Swedish Ladder Drilling Method is described in greater detail in a new Atlas Copco booklet. Write for a copy to your local Atlas Copco company or agent or from the address below.

* Patents pending

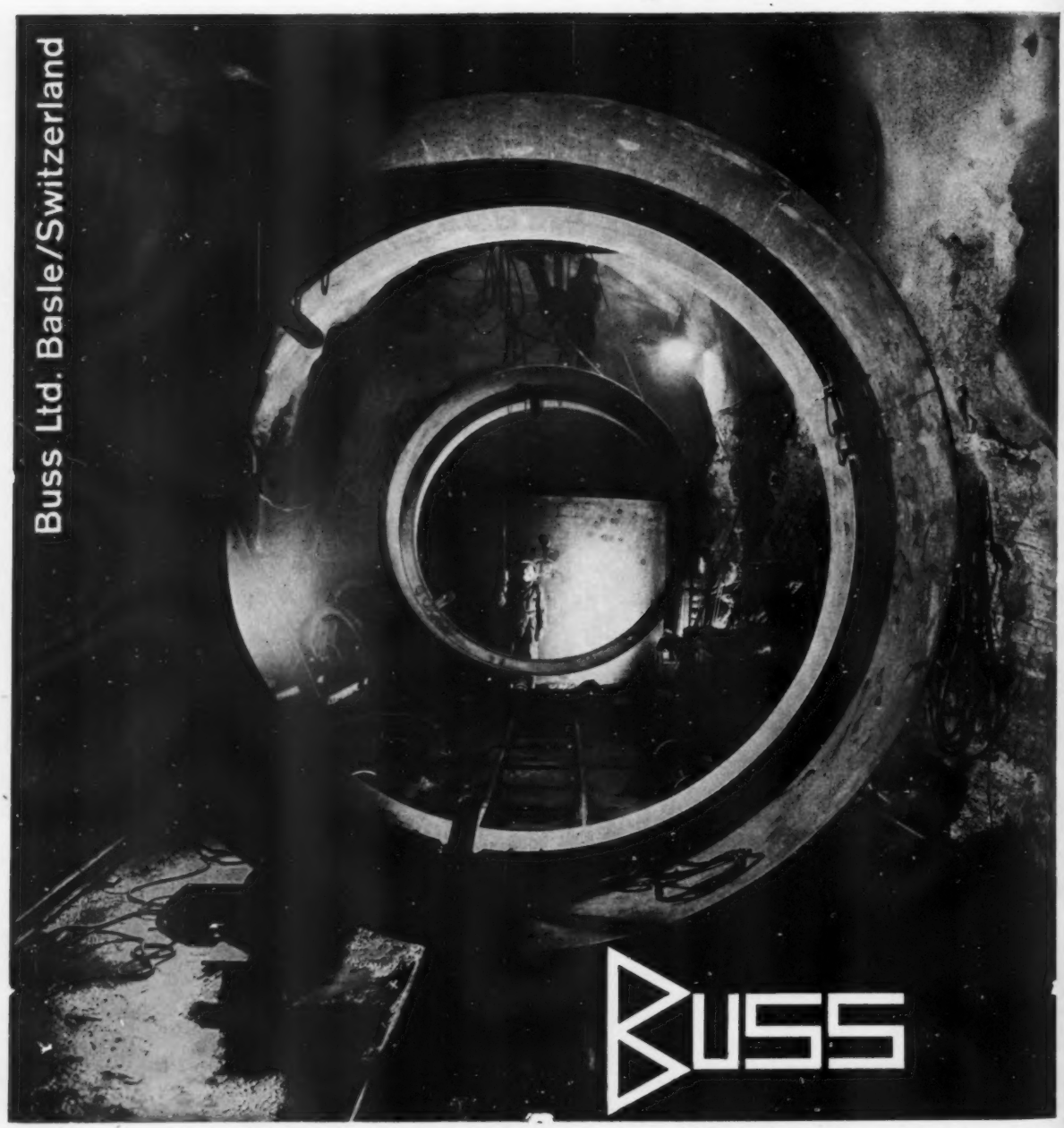
Atlas Copco

PUTS COMPRESSED AIR TO WORK FOR THE WORLD

ATLAS COPCO AB, STOCKHOLM 1, SWEDEN

specialized

in penstocks and pressure shaft linings as well as in other equipment for hydro-electric power plants



again - a mile a month!

Once again Mitchell Construction are driving hard rock tunnels in the Scottish Highlands at the rate of over a mile a month.

Every month over half a million feet of drilling for explosives, every month the firing of about 85 tons of gelignite, and every month 50,000 cubic yards of rock to be brought to the surface

This is what is happening at Strathfarrar, Inverness-shire, where, in addition to 15 miles of tunnel, the Company are constructing two dams and two underground Power Stations for the North of Scotland Hydro-Electric Board.

Twice before—at St. Fillans and at Killin—Mitchell Construction have driven urgently required tunnels at this speed—an achievement which vividly reflects the planning, organisation, and teamwork which are the essential features of the Company's work in every field of building and civil engineering construction.

MITCHELL CONSTRUCTION

Building and Civil Engineering Contractors

THE MITCHELL CONSTRUCTION COMPANY LTD.

WHARF WORKS, PETERBOROUGH.

CONSULTING ENGINEERS:

Sir William Halcrow & Partners, Consulting Engineers, Stanhope House, 47 Park Lane, London, W.1

modern control

sets a new standard

of electric operation

ONLY BUCYRUS-ERIE EXCAVATORS INCORPORATE THIS NEW CONTROL

A few of the facts:

No excessive heat loss, even in stall conditions.

Torque increase; speed reduction, in heavy digging operations.

Gradual turns are possible in either direction, without forward-reverse jockeying—even on hard quarry floors.

No operating clutches. Separate power sources are used to control each specific operation. Full power up and power down for hoisting and lowering.

Crowd machinery is mounted on the revolving frame—not on the boom—so that the weight is effectively used without reducing front-end output. Digging ranges are greater than any other electric or diesel of similar capacity.

MORE FACTS about this new Bucyrus-Erie electric control are available on application.

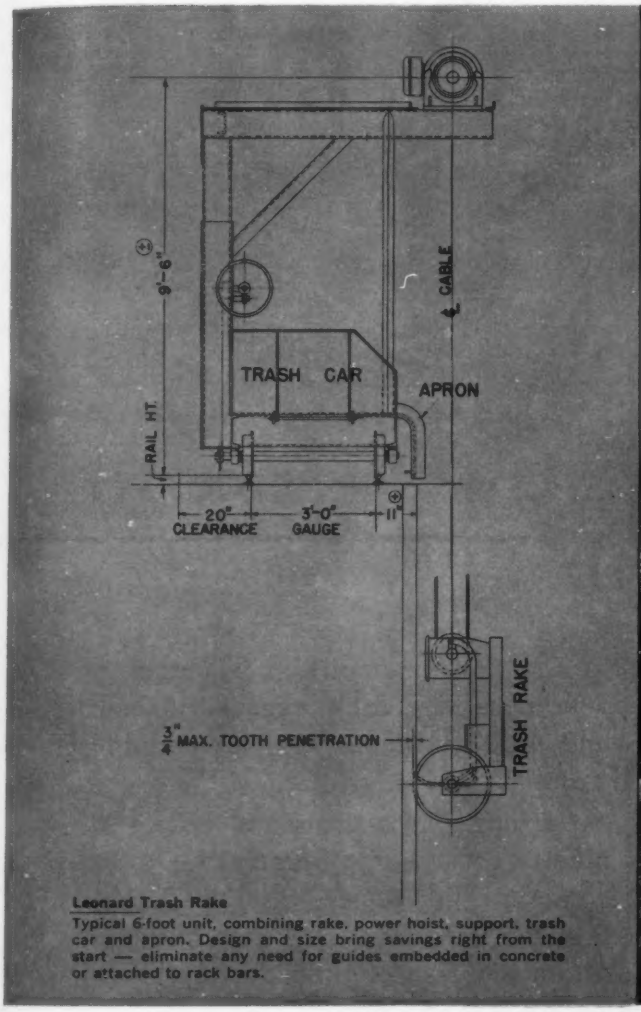
BUCYRUS ERIE

BUCYRUS-ERIE COMPANY

South Milwaukee, Wisconsin, U.S.A.

RUSTON-BUCYRUS LIMITED, LINCOLN, ENGLAND

ALLIS-CHALMERS



Leonard Trash Rake
Typical 6-foot unit, combining rake, power hoist, support, trash car and apron. Design and size bring savings right from the start — eliminate any need for guides embedded in concrete or attached to rack bars.

Cleans up costly head losses

. . . rakes-in savings enough to pay for itself!

Here's intake-trash removal so far ahead of hand methods that *"once sold is sold forever!" Leonard* trash rake installations deliver savings both in reduced head loss and labor costs. And they bring a permanent solution to shortages of people to do the job — make trash removal a one-man operation.

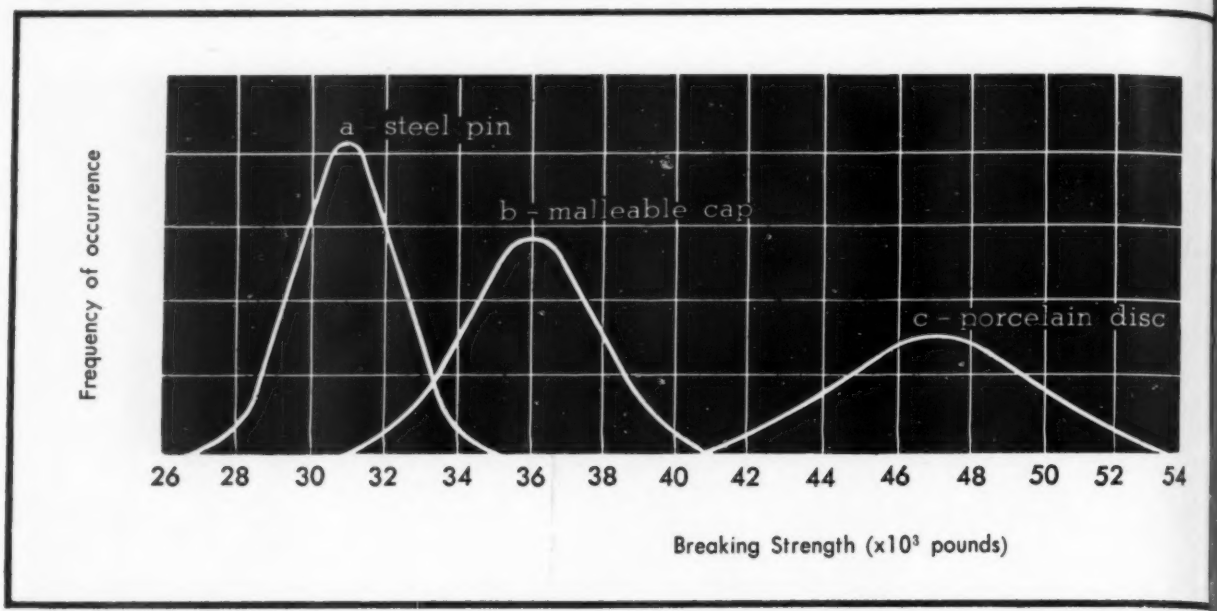
Leonard trash rakes roll right down your existing rack bars whether vertical or inclined. Because no channel guides are needed, they freely ride over stubborn obstructions, dig them loose, scoop trash up to the waiting receptacle or car. Self-dumping units also are available—both log-grapple and regular models.

Leonard is an Allis-Chalmers trademark.

With Allis-Chalmers trash rakes even the initial investment is low. Width is held to the logical minimum required for adequate handling of trash . . . standard 6- and 8-foot sizes. Larger units special. Your nearby A-C representative has full details. Or write **Allis-Chalmers,** Hydraulic Division, York, Pa.

A-1307

SUPERIORITY IN PORCELAIN


a - steel pin
b - malleable cap
c - porcelain disc
Frequency of occurrence
26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
Breaking Strength (x10³ pounds)

UNIFORMITY
STRENGTH
DURABILITY

UNIFORMITY? ..... no matter how good an insulator you choose you can't expect maximum efficiency and service unless they're uniformly balanced in strength.

Take, as an example, the standard NGK 10″ ball and socket disc insulator (rated 25,000 lbs. E & M Strength) and review the mechanical strength of each component by the histogram above. Uniform mechanical breakdown strength, always occurring at the pin, of the NGK Insulator unit is shown by Curve a; that of the cap by Curve b when a special pin is used; that of the porcelain by Curve c when using a special high strength cap and pin.

Insulator uniformity at a high level is your prime assurance to safe operation and maintenance economy.

You get so much more out of **NGK** *Insulators*

Nippon Gaishi Kaisha LTD.
MIZUHO NAGOYA JAPAN

Cable: INSULATOR Nagoya. TELEX: NGK-NG9928
Represented in all major territories

Extra-high-voltage Power transformers

Three-phase ratings up to 600 MVA and 400 kV

Brown Boveri transformers are impulse tested, efficient, noteworthy for their compactness, and have a long-established reputation for reliability in service.

At present under construction :
two 400-MVA banks, 420 kV, for the Kraftwerke Hinterrhein A.-G., Thusis, Switzerland, and
one 420-MVA bank, 380 kV, for an installation in Finland

Single-phase transformer belonging to a 150-MVA bank for a Swedish 380-kV installation.

BROWN BOVERI

BROWN, BOVERI & CO. LTD., Baden - Switzerland

Representatives in most countries

Our list of products includes :

Steam and gas-turbine power stations • Machinery and apparatus for nuclear power stations • Equipment for hydro-electric and diesel stations

Regulating and protective gear • Generators

Transformers, airblast circuit-breakers, instrument transformers for 400 kV

Electric motors • Electric furnaces • Electric welding equipment • Transmitting and rectifier tubes

Electrical equipment for locomotives, trams and trolleybuses • Marine drives

HITACHI

Another Big Hydraulic Turbine and Generator by Hitachi

Hitachi has recently completed two 137,500 kW/125,000 kVA hydraulic turbines and generators for the Miboro Power Station in Central Japan. The turbine is of the vertical-shaft Francis type, and specified for a speed of 225 r.p.m., a maximum effective head of 200m and 76.6 cu.m/sec. water flow, making it one of the largest units of its kind in the world. Its runner has a maximum diameter of 3.7m and the main shaft a diameter of 95cm. The spiral casing, which was constructed in 13 sections to facilitate transportation to the site, has an inlet diameter of 3.35m and an outer diameter of 11.2m.

The generator presents a high-torsoed appearance, having been so designed in consideration of the comparatively high speed. Since the generator was designed for a rated voltage of 16,500 volts and, in this respect, represents the first such attempt in Japan, particular care was taken in the corona-shielding and impulse resistance of the stator winding. The generator is rated at 60 cycles, 225 r.p.m. and 0.9 power factor, but is also capable of operating at 50 cycles, 187.5 r.p.m. and 1.0 power factor.

Hitachi, Ltd.
Tokyo Japan
Cable Address: "HITACHY" TOKYO

Dam Building

and similar work . . . . .

A BUTTERS CRANE

designed for the purpose

Specially devised for erection in difficult situations the Butters Monotower Crane combines

Great height of lift

Large radius

Full circle coverage

on a

very small erection area

The photograph shows a typical example; this is an electric crane with a maximum capacity of 5 tons and a maximum radius of 100 feet, operating through a full circle.

We shall be pleased to send particulars of our Monotower Cranes, or of any other type on request

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Hillingdon, Middx.

Telephone: Uxbridge 3925 and 2288

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Princess House, 71 Temple Row, Birmingham, 2

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From Pakistan, to Greece or anywhere in the world

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BUTTERFLY VALVES

offer a BIG list of advantages

- ★ Leak-tight shut off.
- ★ Great economy in space, compared with gate or globe valves. 2/3 of weight approx.
- ★ No fouling, low pressure drop.
- ★ Easy operation.
- ★ Simple, solid design of body, disc and shaft. Great strength, minimum maintenance.
- ★ International servicing available.

Thirty-six COCKBURN-ROCKWELL Butterfly Valves in sizes up to 72″ diameter were recently supplied on a Pakistan Power Station Contract. A further thirty valves, 48″ to 72″ diameter, are now being installed in the Athens Water System extension.

COCKBURNS LTD Cardonald Glasgow SW1

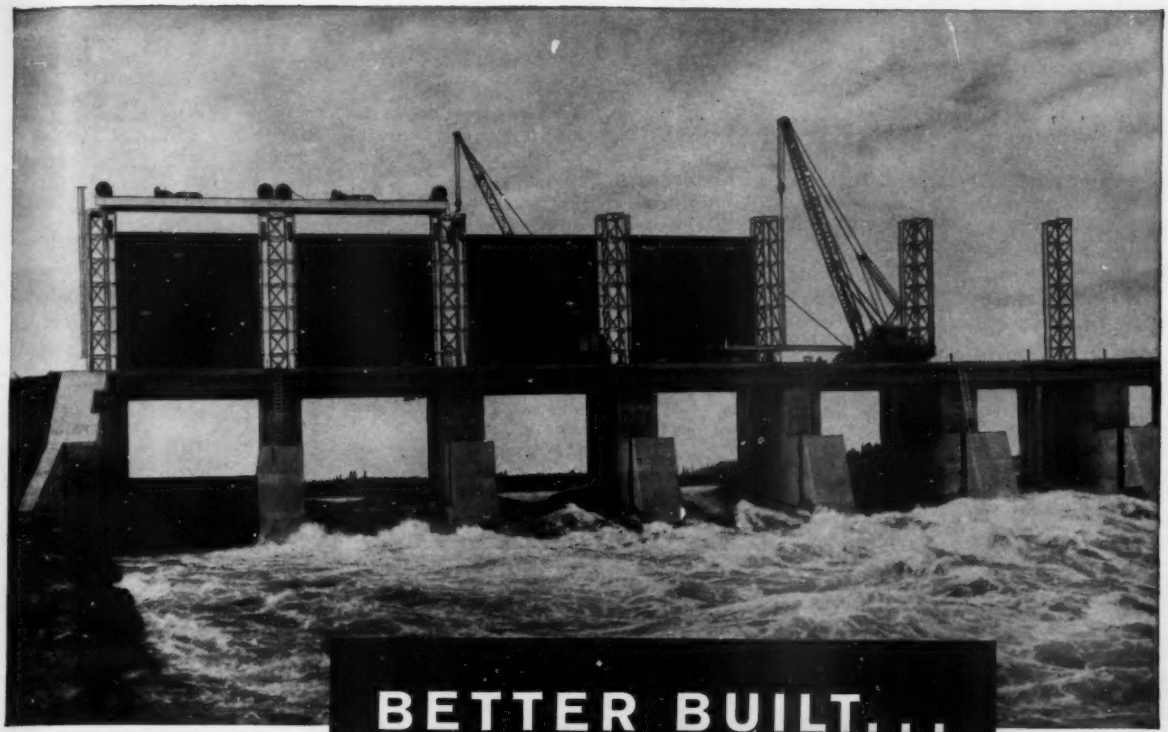


Photo by courtesy of Manitoba Hydro Electric Board.

BETTER BUILT... for better service

Participation in the great Kelsey Generating Station development on the Nelson River was a privilege highly prized by Canadian Vickers. Being entrusted with the manufacturing of nine Sluice Gates with Control Equipment and Embedded Parts bespeaks the confidence placed in the plant facilities, the meticulous engineering and skilled craftsmanship of Canadian Vickers Limited.

CANADIAN VICKERS LIMITED

MONTREAL • TORONTO

MEMBER OF THE VICKERS GROUP

Hydraulic Gates Of All Types • Turbines • Penstocks • Butterfly Valves • Gantry & Power House Cranes • Water Control Equipment Of Every Nature.

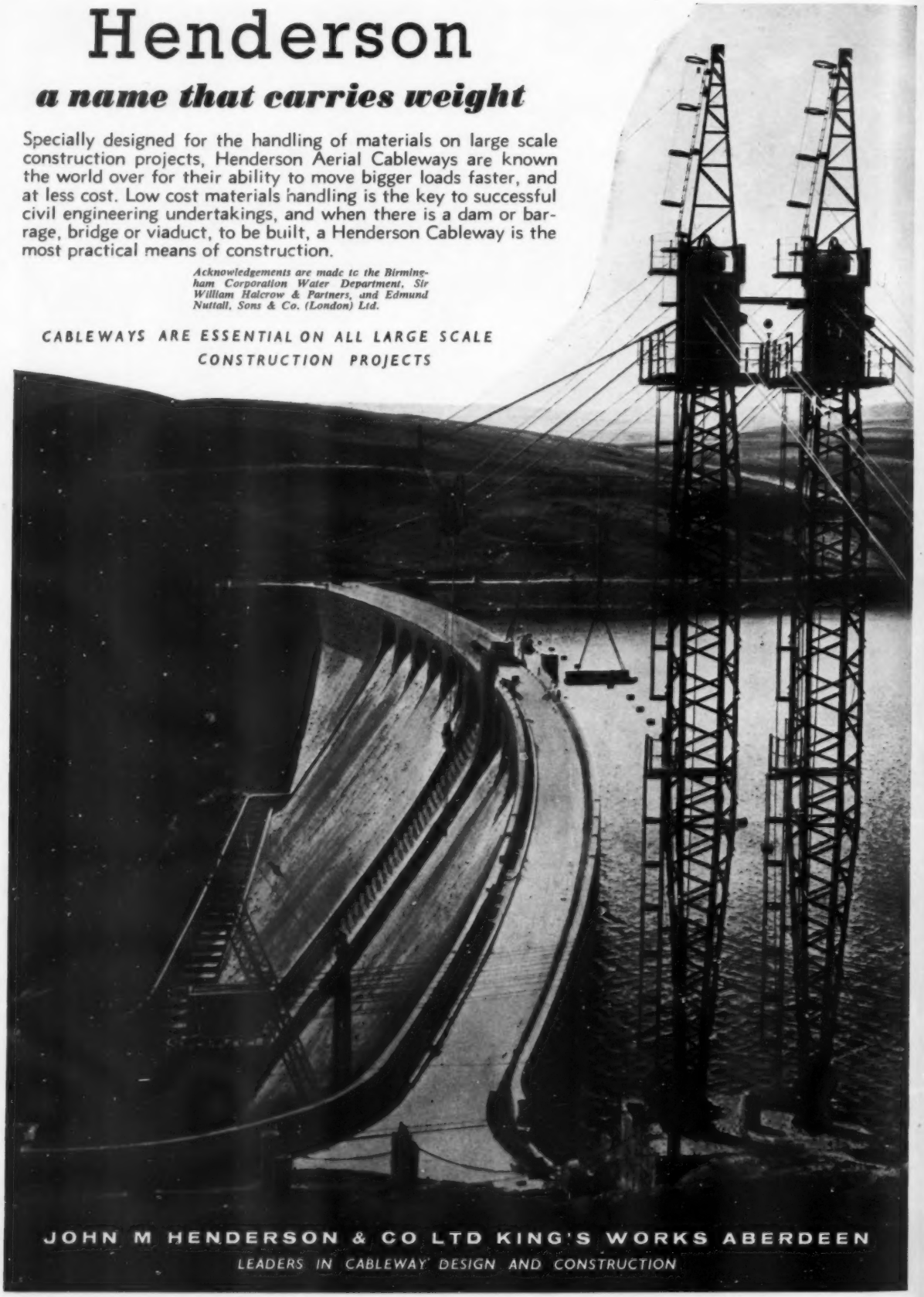
Henderson

a name that carries weight

Specially designed for the handling of materials on large scale construction projects, Henderson Aerial Cableways are known the world over for their ability to move bigger loads faster, and at less cost. Low cost materials handling is the key to successful civil engineering undertakings, and when there is a dam or barrage, bridge or viaduct, to be built, a Henderson Cableway is the most practical means of construction.

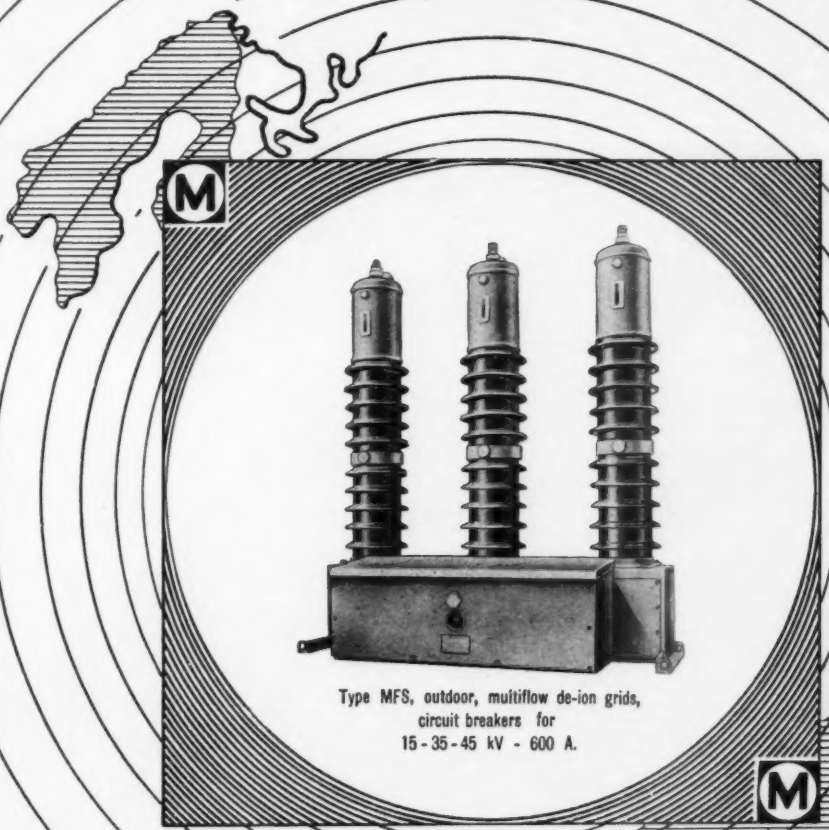
Acknowledgements are made to the Birmingham Corporation Water Department, Sir William Halcrow & Partners, and Edmund Nuttall, Sons & Co. (London) Ltd.

CABLEWAYS ARE ESSENTIAL ON ALL LARGE SCALE CONSTRUCTION PROJECTS



JOHN M HENDERSON & CO LTD KING'S WORKS ABERDEEN

LEADERS IN CABLEWAY DESIGN AND CONSTRUCTION



Type MFS, outdoor, multiflow de-ion grids,
circuit breakers for
15 - 35 - 45 kV - 600 A.

MAGRINI'S TRADE-MARK AND SWITCHGEAR WIN WORLD-WIDE RECOGNITION

MAGRINI S.P.A. - VIA I. MAGRINI 7 - BERGAMO - ITALY

"WOOD STAVE for HYDRO-ELECTRIC PIPELINES"

In rugged mountain and fertile valley this versatile conduit has demonstrated unparalleled economy and ease of construction.

Wood stave pipe is assembled from manufactured components easily shipped to the most remote sites. It can be constructed over the most difficult terrain and complex contours by local labour. For these reasons, wood stave pipe is frequently the only economic solution available for penstocks, high-line conduits or irrigation projects.

Our recent publication: *CONTINUOUS STAVE WOOD PIPE*, reveals details of history, uses, construction and maintenance, together with design data and flow tables.

Write for your copy.

CANADIAN WOOD PIPE & TANKS LIMITED

550 Pacific Street,
Vancouver 2, British Columbia,
Canada

HOMOGENEOUS INSULATION THROUGHOUT!

that's the Pirelli-General paper tube joint

Pioneered by Pirelli-General over 35 years ago, the paper tube joint continues, basically unchanged, to be successfully used for designs up to 330 kV.

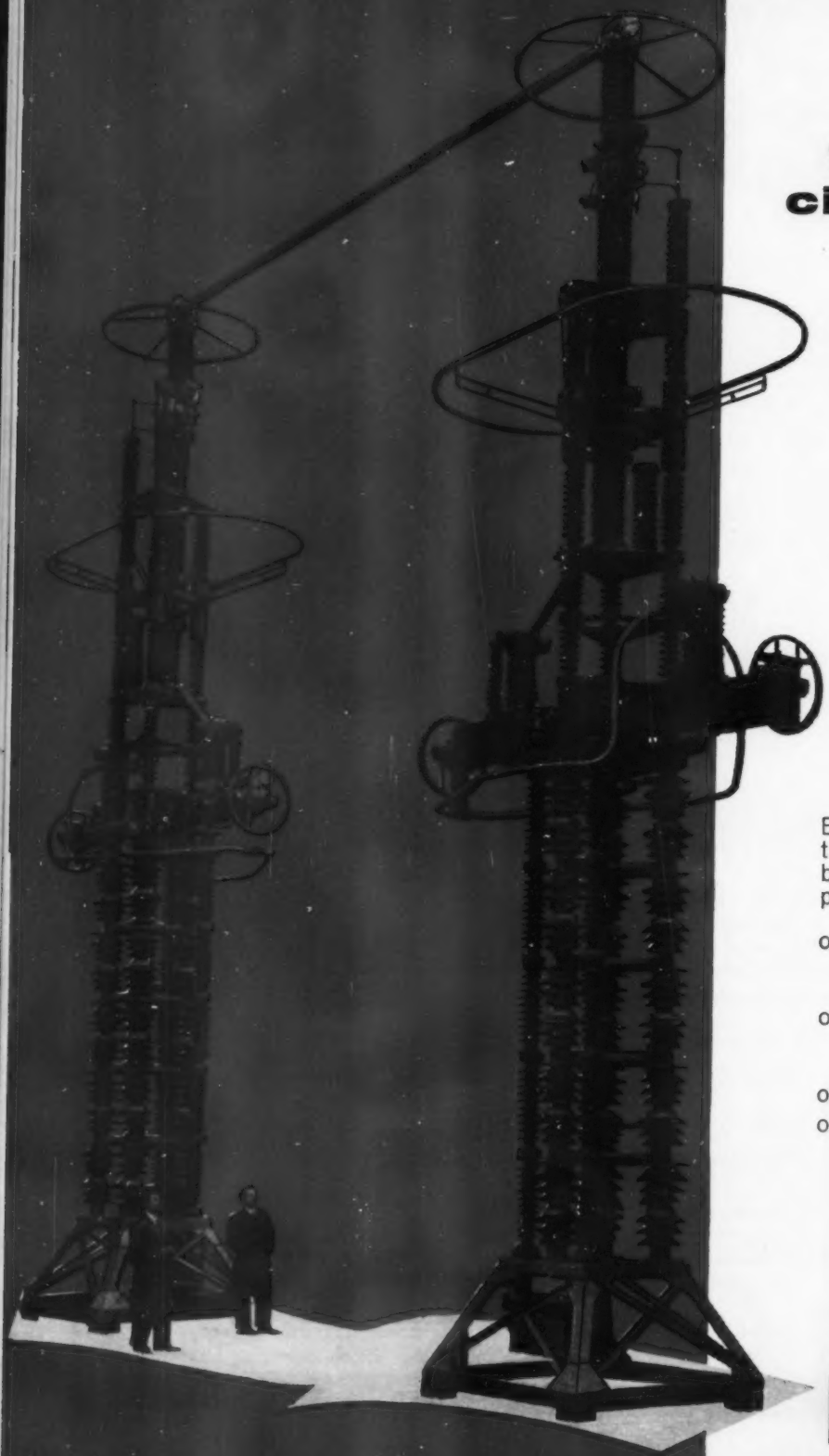
There are good reasons for this. Paper tube insulation is homogeneous throughout, ensuring excellent electrical properties and mechanical support of the joint cores, and can be applied with greater tension than paper tapes and at much higher temperatures. It also requires much less handling than other joint insulation methods. Furthermore, the amount of insulation is predetermined for various voltages and is never left to the judgment of the jointer.

pg

PIRELLI-GENERAL CABLE WORKS LIMITED

SOUTHAMPTON AND EASTLEIGH

FOR THE WORLD'S HIGHEST VOLTAGE RA



One of the poles of a series of 525 kV, 25,000 MVA, AE 17 air blast circuit breakers, for the equipment of the U.R.S.S.

the air blast circuit breaker

type AE

A range of breakers
from 70 kV to 525 kV
Breaking capacity :
30,000 amp. rms.

Besides properties peculiar to the technique of air blast circuit breakers the type A E apparaters provides :

- o Breaking with high r. r. r. v. and ability to interrupt a kilometric fault.
- o Breaking of currents in unloaded power transformers with low overvoltages
- o Low air consumption.
- o Negligible burning of contacts.

Ateliers de Constructions Electriques de

Delle

25 CHEMIN DE CYPRIAN VILLEURBANNE (RHONE)

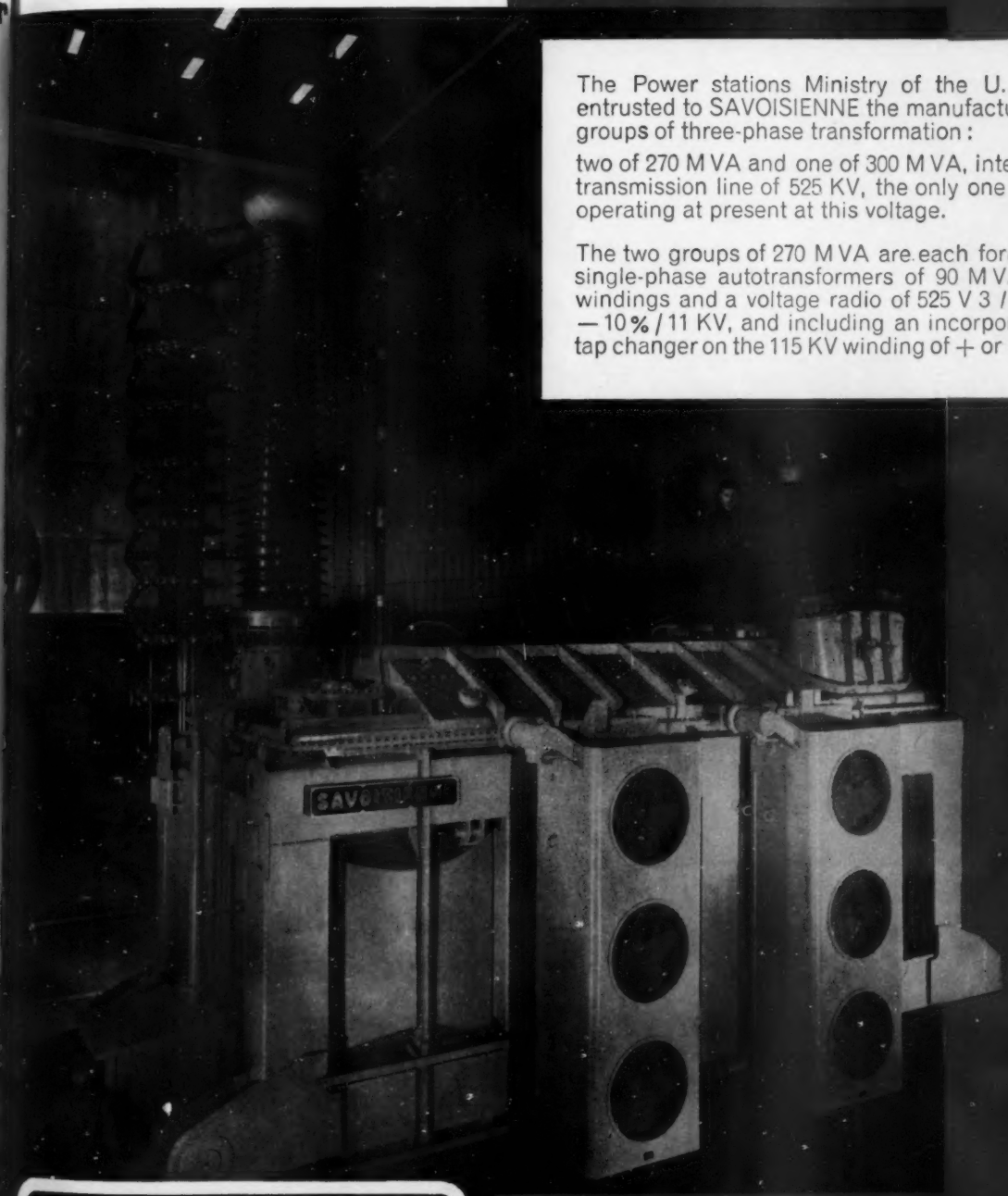
OF THE "COMPAG NER

TRANSMISSION LINE 525 KV

The Power stations Ministry of the U. S. S. R. has entrusted to SAVOISIENNE the manufacturing of three groups of three-phase transformation :

two of 270 M VA and one of 300 M VA, intended for the transmission line of 525 KV, the only one in the world operating at present at this voltage.

The two groups of 270 M VA are each formed by three single-phase autotransformers of 90 M VA with three windings and a voltage radio of 525 V 3 / 115 V 3 + or — 10 % / 11 KV, and including an incorporated on-load tap changer on the 115 KV winding of + or — 10 % steps.



The first transformer has successfully supported the final tests in the new SAVOISIENNE laboratory at Aix-les-Bains equipped with an impulse voltage generator of 175 Kilojoules whose maximum voltage reaches 4 400 000 volts.

SAVOISIENNE

AIX-LES-BAINS (Savoie)

"GENERALE D'ELECTRICITE"

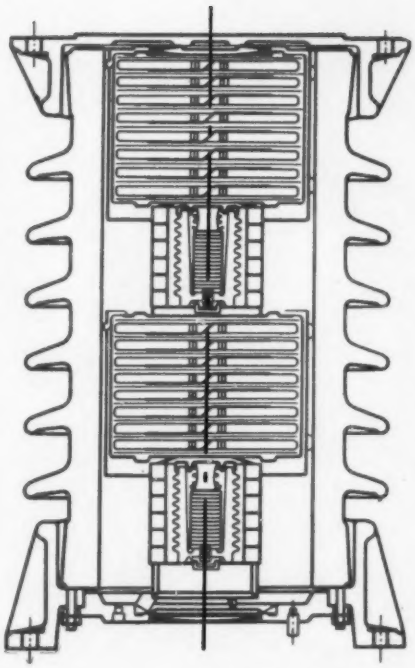
CHARMILLES

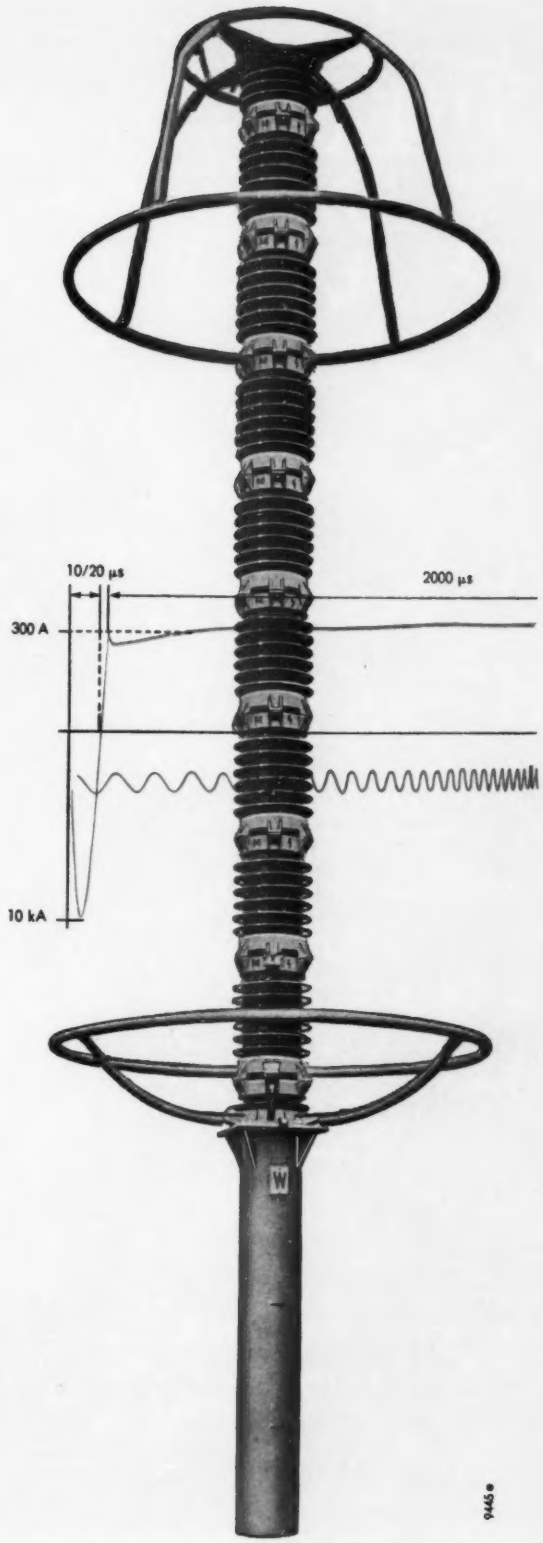
HYDRAULIC TURBINES

—CHARMILLES ENGINEERING WORKS LTD., GENEVA—

TWO 88,000 HP VERTICAL SHAFT, FOUR-JET IMPULSE TURBINES FOR BRAZIL

AEG





Lightning arresters

of self-supporting design
for highest voltages

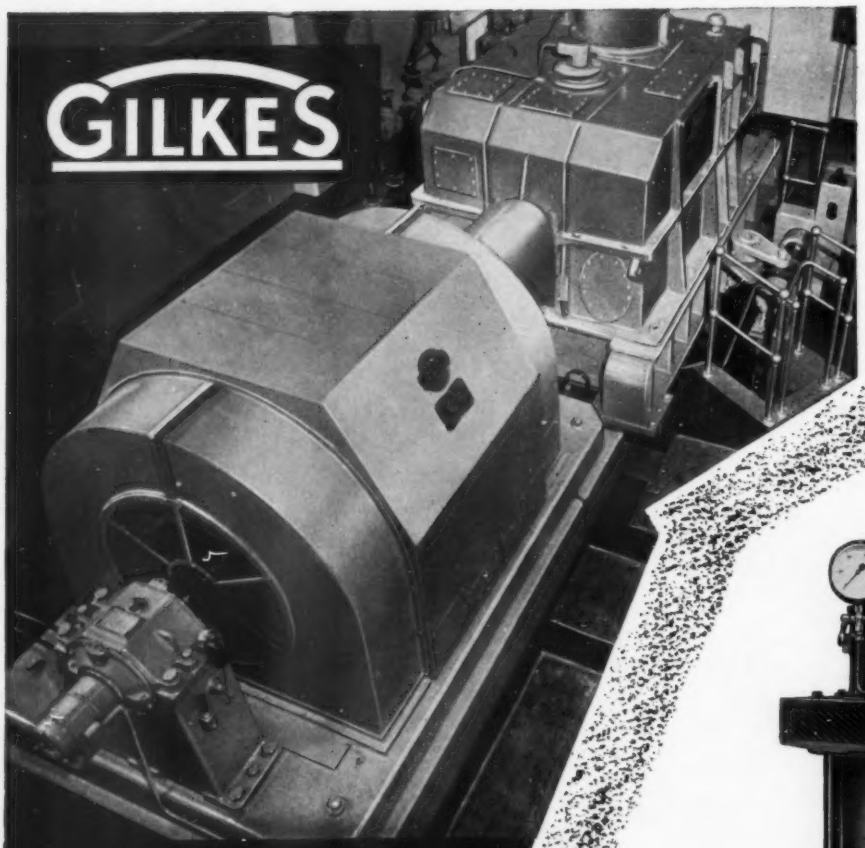
Type AV

Voltage rating 340 $kV_{r.m.s.}$
50% Breakdown voltage 730 - 860 $kV_{(max)}$
(1/50 µs wave)
Residual voltage < 1155 $kV_{(max)}$
(discharge current 10 kA)

ALLGEMEINE ELEKTRICITÄTS-GESELLSCHAFT

Berlin (West) EXPORT DEPARTMENT Frankfurt (Main)

GILKES



Left:
The North of Scotland Hydro-Electric Board's Mullardoch underground power station, Glen Affric. This contains a 3,600 horsepower, vertical shaft GILKES Francis turbine driving a 2,400kW Bruce Peebles induction generator through a speed increasing gear unit.

ASYNCHRONOUS HYDRO-ELECTRIC UNITS

for all heads and outputs

Suitable for remote controlled or fully automatic installations, the water turbine driven induction generator provides a simple and economic source of power for operation in conjuction with conventional synchronous plant.

Gilkes specialise in the manufacture of asynchronous hydro-electric plant and have a wide experience in the design of all types of unit.

Above:
A 48kW induction generator driven by a 71 horsepower GILKES Francis turbine. This unit is installed in the Lochay Fish Pass, part of the North of Scotland Hydro-Electric Board's Breadalbane Scheme.

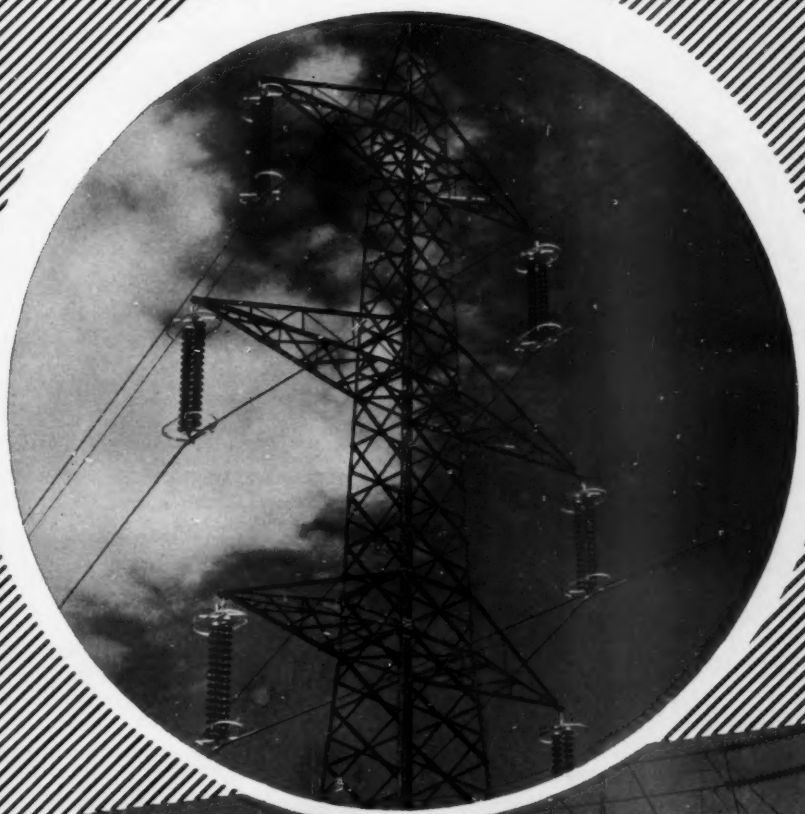
GILBERT GILKES & GORDON LTD

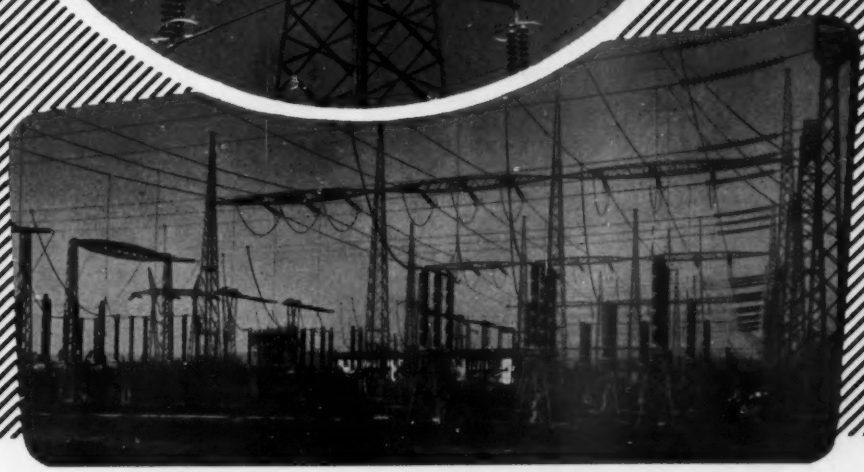
WATER TURBINE & PUMP MANUFACTURERS

KENDAL Telephone: Kendal 28 **ENGLAND**

London Office: CRAVEN HOUSE, KINGSWAY, LONDON W.C.2 Telephone: HOLBORN 3231

SALVI





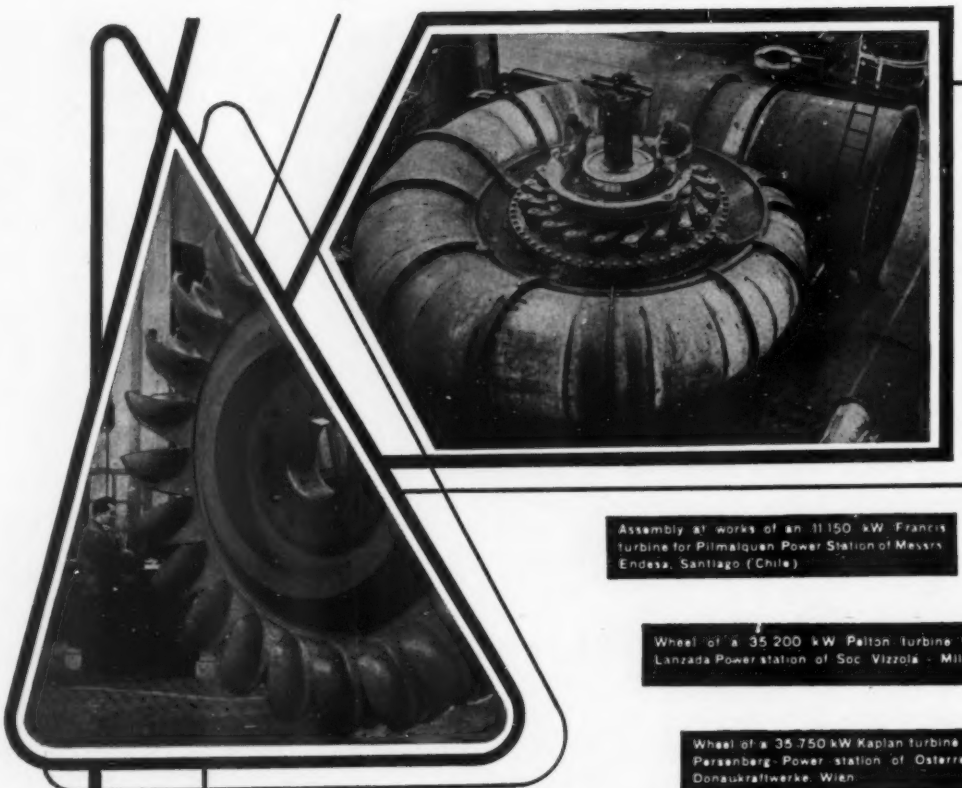
For 30 years Messrs. A. Salvi and Company, Milano, Italy, have specialized in the design and manufacture of complete equipment for Overhead Transmission Lines, including Compression Dead End Assemblies and Joints. The Works of the Salvi Company are engaged exclusively in the production of high grade fittings for High Voltage Transmission Systems, up to and including voltages of 220/380 KV and for all sizes of Copper, A.C.S.R. and Aluminium Alloy Conductors.

SOLE REPRESENTATIVES IN THE UNITED KINGDOM AND THROUGHOUT ALL DOMINION COUNTRIES (EXCEPT AUSTRALIA AND NEW ZEALAND) AND BRITISH COLONIES AND PROTECTORATES

THE ENGLISH SALVI COMPANY LTD., West Road, Northumberland Park, Tottenham, London, N.17

Telephone: TOTTENHAM 6611

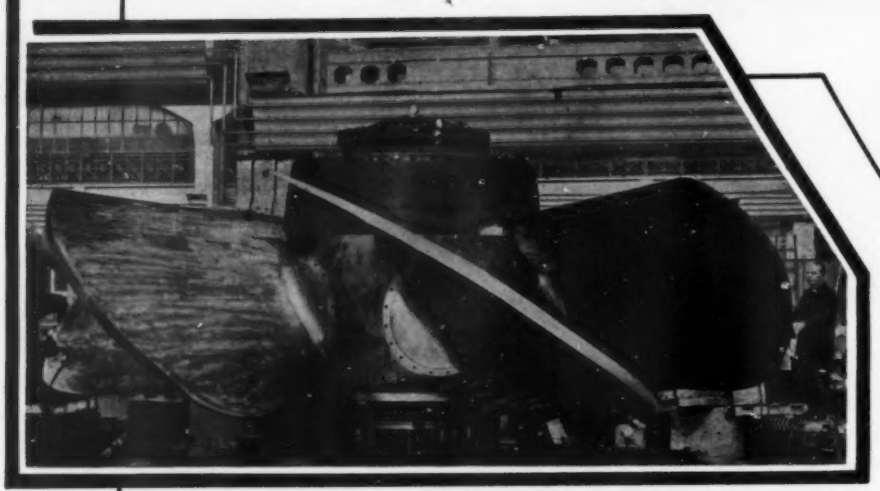
Complete hydro-electric plants



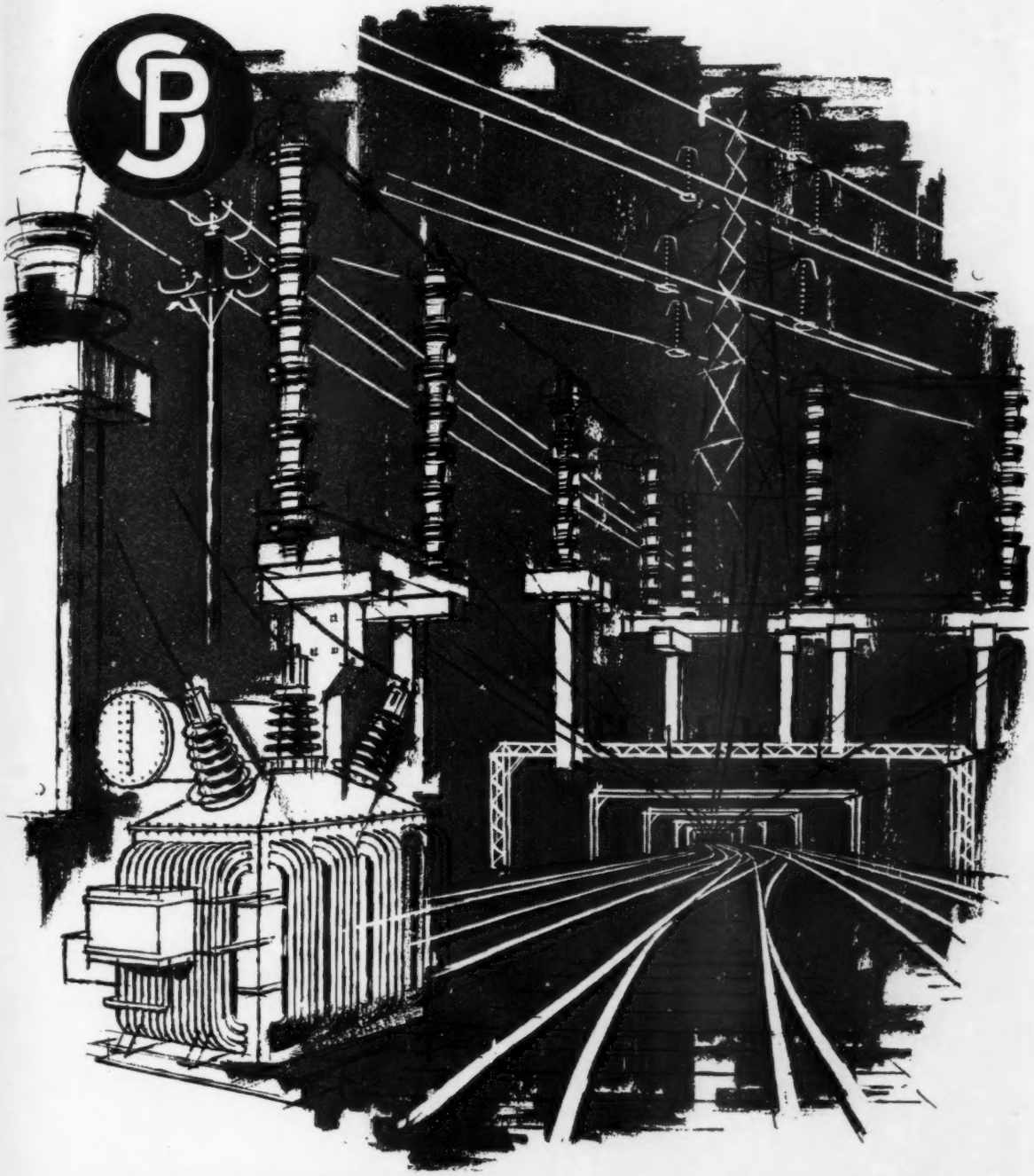
Assembly at works of an 11 150 kW Francis turbine for Pilmaiquen Power Station of Messrs Endesa, Santiago (Chile)

Wheel of a 35 200 kW Pelton turbine for Lanzada Power station of Soc Vizzola - Milan

Wheel of a 35 750 kW Kaplan turbine for Ybbs Persenberg - Power station of Osterreichische Donaukraftwerke, Wien



ANSALDO-SAN GIORGIO
GENOVA



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The outstanding quality of S & PP insulators is the result of over 30 years' experience in the manufacture of high voltage porcelain insulators.

- **Overhead line insulators**
- **Switchgear post insulators**
- **Transformer bushings**
- **Insulators for railway electrification**
- **Custom-made porcelains**

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Hydro-Electric Generators

BRUCE PEEBLES
EDINBURGH

Interior of Shin power station of the North of Scotland Hydro-Electric Board showing two 12 MW 11 kV 375 r.p.m. generators.

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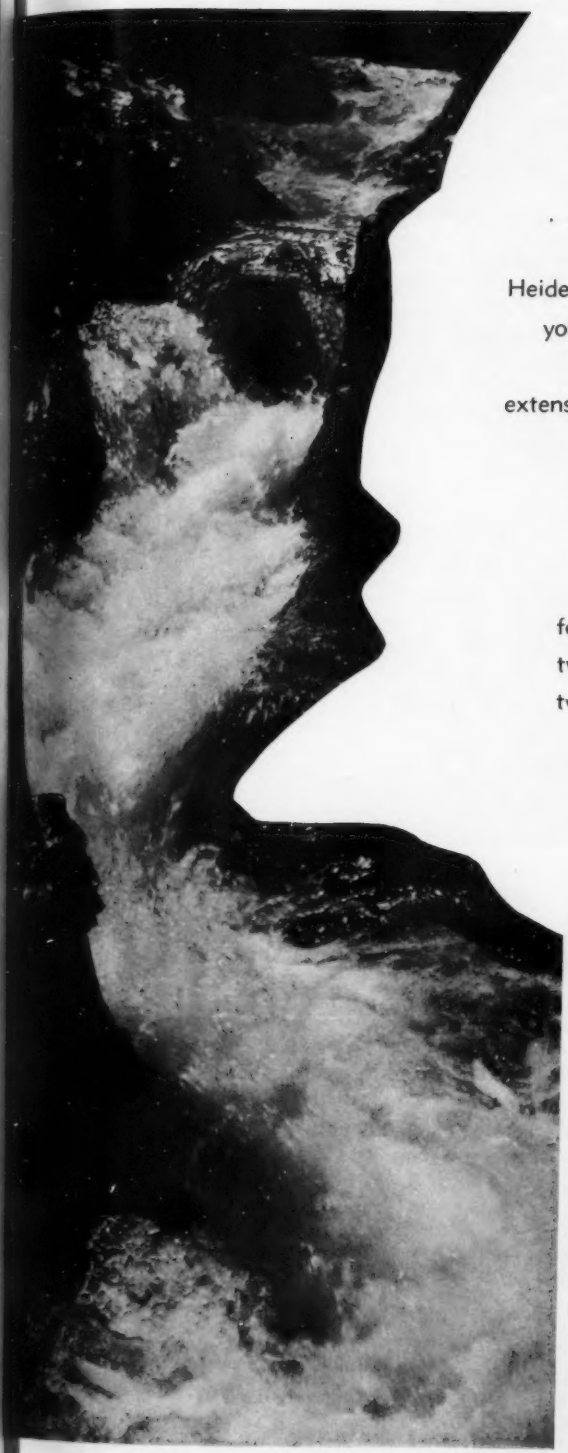

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The workshop photo shows one runner each of the above mentioned turbines

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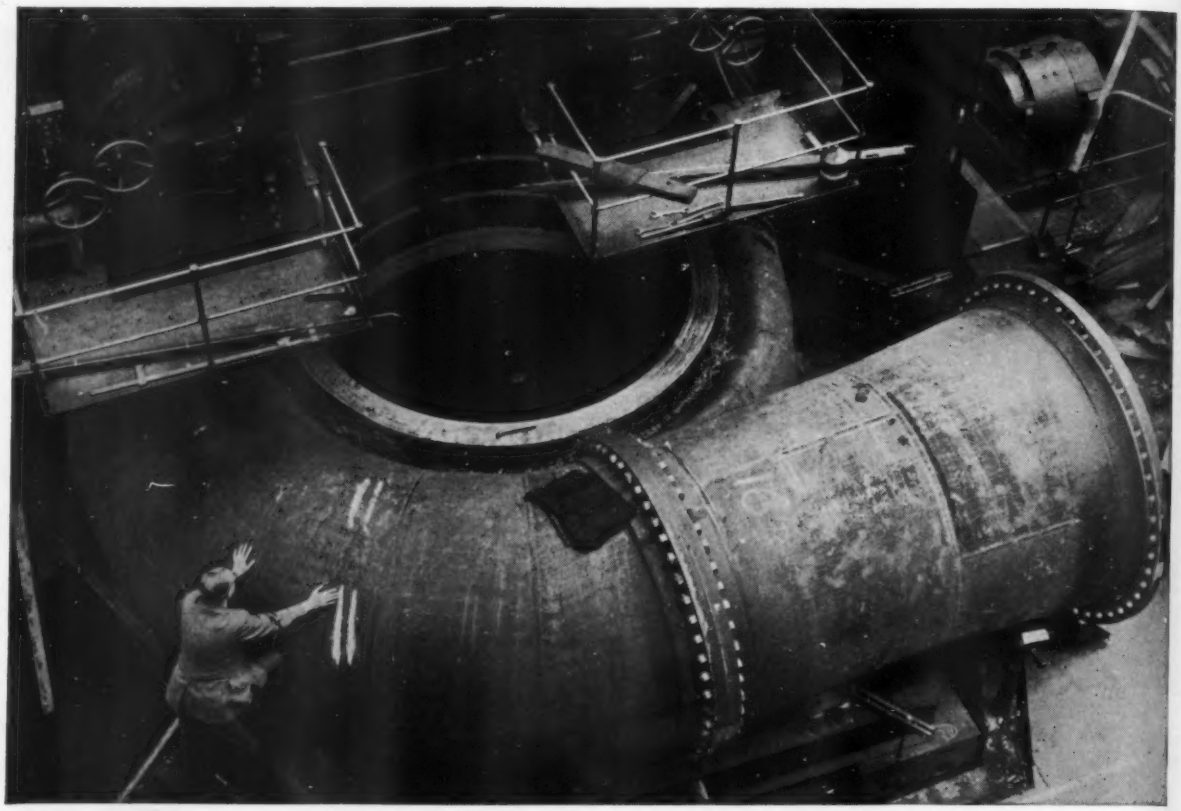

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CONTENTS FOR NOVEMBER, 1960

Editorial: The Indus Water Treaty - - - 413

Editorial Notes - - - - - - 414

Correspondence: Niagara River Flow - - - 416
By L. T. Higgins
D. J. Davies

Slapy Power Station—II - - - - - 417
By Prof. Ing. Dr. Miroslav Nechleba

Hydrology at Helsinki—I - - - - 421

The Use of a Mean-Value Characteristic in Pipe-Flow Measurements by Current Meters - - - 424
By F. A. L. Winternitz, Dipl. Ing., E.T.H., Dr. Tech., A.M.I.Mech.E., A.F.R.Ae.S., V.D.I., and J. N. Mansfield, B.Sc.

Warsak Hydro-Electric Project—I - - - 431
By T. J. Martin, B.Sc.Tech., M.E.I.C., M.ASCE.

Symposium on Hydraulic Turbine Research—I - - 437

Book Reviews - - - - - - 444

Short Articles: Control of Evaporation Losses—Zeiss Ecomat and Co-ordimat Units—Whitlock Earth-moving Equipment—Hamilton Falls Development - 446

Abstracts from the World Technical Press - - 450

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WATER POWER

A technical journal devoted to the study of all aspects of hydro-electric development

The Indus Water Treaty

THE Indus Water Treaty, which was signed on September 19 by Shri Jawaharlal Nehru, Prime Minister of India, Field Marshal Mohammad Ayub Khan, President of Pakistan, and Mr. W. A. B. Iliff, Vice-President of the World Bank, is the outcome of nine years of patient negotiation and is a testimonial both to the good sense of the two countries concerned and to the wisdom displayed by the World Bank. Indeed, for the World Bank the Treaty may be regarded as a triumph, because it was due to the initiative of Mr. Eugene R. Black, President of the Bank, in approaching the two governments in 1951 that technical studies and discussions were commenced in 1952, and were sponsored by the Bank up to their successful conclusion.

The Indus is one of the world's great rivers and feeds the largest irrigation system in the world, supporting 40 million people in Pakistan and 10 million in India. Hitherto, however, irrigation has depended on river flow and has been subject to seasonal fluctuations and to variations from year to year. Storage works are therefore a prime necessity.

Even before partition in 1947, conflicting water claims were under dispute between the Sind and Punjab provinces, but partition drew the border right across the Indus system, leaving India in control of much of the headwaters and of the headworks of two of Pakistan's main irrigation canals, Pakistan becoming the downstream riparian. The sharing of the Indus waters thus became a complex international issue.

Apart from two major right-bank tributaries—the Kabul and the Kurram, which flow in from Afghanistan and are not concerned in the Treaty—the Indus is replenished by a fan-shaped network of five major tributaries which join to flow into the left, or eastern bank; from west to east they are the Jhelum, the Chenab, the Ravi, the Sutlej, and the Beas which joins the Sutlej on the Indian side of the border. The basis of the treaty is that the waters of the three westernmost rivers—the Indus, Jhelum and Chenab—shall be at the disposal of Pakistan, whereas the waters of the three easternmost rivers—the Ravi, Sutlej and Beas—shall be controlled by India. This raises the problem of the irrigation system in Pakistan now served by the three eastern rivers, and a series of eight link canals is to be cut to transfer water from the western rivers to supply this system. These canals will be constructed within a transition period of ten years (it may be extended by mutual agreement) during which time India will supply agreed flows from the eastern rivers to Pakistan.

Although the prime purpose of the scheme is irrigation (and to that extent is outside the field of this journal) the Indus is also a valuable source of power, and it is intended that the potentialities in this direction shall be exploited. Indeed, certain resources capable of development independently of international water rights are already in course of being harnessed. Elsewhere in this issue will be found the first of two articles on the Warsak development—a 160 MW plant built on the Kabul River in Pakistan under the auspices of the Colombo Plan Administration in Canada. Again, on the Sutlej River in India is the 400 MW Bhakra-Nangal development, described in our May and June 1954 issues and now rapidly nearing completion.

Two further installations are planned, one in India and the other in Pakistan. In India a large earthfill dam will be built on the Beas River to create a live storage of 5·5 million acre ft. and to provide 200 MW of power capacity. In Pakistan an earthfill dam will be built on the Jhelum River to provide 4·75 million acre ft. of live storage, which will feed power plant of over 300 MW capacity.

A second earthfill dam is also to be constructed in Pakistan, on the upper Indus, to create a live storage of 4·2 million acre ft. purely for irrigation. This and the Jhelum reservoir will be able to place the irrigation supplies in Pakistan on a firm basis and will make possible substantial new irrigation development.

Of the total works to be executed under the Treaty by far the larger proportion will be carried out in Pakistan. In addition to the two dams, power plant, and the eight link canals already mentioned, together

with ancillary works, 2,500 tubewells are to be put down to overcome waterlogging and salinity in irrigated areas totalling 2,500,000 acres. All this work will be the responsibility of the West Pakistan Water and Power Development Authority (WAPDA).

The financing of such a colossal project is itself a major undertaking. The Indus programme is believed to be the largest of its kind ever to be undertaken anywhere, and the total cost is estimated to be $1,070 million (£380 million) of which $870 million (£310 million) will be spent in Pakistan and the remainder in India. An Indus Basin Development Fund has therefore been established under the auspices of the World Bank which will provide aggregate resources in foreign exchange and in Pakistan rupees of about $894 million (£320 million). On the foreign-exchange side India will contribute £62,060,000 and Pakistan £440,000, the World Bank will make a loan of $80 million, the United States Government a loan of $70 million, and the remaining foreign exchange will be provided by grants from the Governments of Australia, Canada, Germany, New Zealand, the United Kingdom, and the United States. Pakistan rupees will be provided to the equivalent of $235 million from the United States and to the equivalent of £9,850,000 by Pakistan. The Indus Basin Development Fund will not cover the Beas project, which will be financed separately.

This successful resolution of a critical and long-standing dispute is not only a happy augury in the political field but it should do much to enhance the material wellbeing of the populations concerned.

Alaskan 4,760 MW Scheme

A DAM which the U.S. Army Corps of Engineers are proposing to build in Rampart Canyon on the Yukon River in Alaska will form, it is claimed, the world's largest hydro-electric power development and provide the largest man-made lake. This is, of course, based on present-day comparisons. The location of the Rampart Canyon dam site is about 100 miles north-west of Fairbanks.

The dam itself will be a concrete gravity structure 1,300 ft. long at the present water level of the Yukon River and 2,700 ft. at the crest. The dam will be 500 ft. high and will have a useful head of around 440 ft., whereas the regulated flow is estimated at 118,000 cu. ft. per sec.

The impounded water will form a reservoir covering an area of some 10,700 sq. miles, which is larger than that of Lake Erie (9,940 sq. miles) and over five times that of Lake Kariba (2,000 sq. miles). This lake will be some 150 miles long by 50 miles wide and will have a storage capacity in the region of 1,300 million acre-ft. of water or ten times that at Kariba (130 million acre-ft.). Because of the great volume of impounded water the seasonal drawdown is not expected to be greater than 4 ft. A lake of this size would undoubtedly have a modifying effect on the climate of interior Alaska, and in this particular case it is expected to lengthen the growing season by six frost-free days by acting as a store of summer heat. The recorded temperatures in the area are from 100°F. above to 70°F. below zero. The flooded land will present no particular social or legal problems as the area is uninhabited except for a few Indian villages and contains neither roads nor railways. The lake would take 20 years to fill.

A three-year $1 million study of the project is envisaged, and when the study is completed it would take two years to design the dam and a further eight years to build. The project is estimated to cost between $1,000–1,500 million on the basis of the preliminary studies whereas the power cost to the consumer at the site would be about three mills per kWh of firm energy. The total installed capacity of the Rampart Canyon project will be 4,760 MW, developed by 17 generators of 280 MW each, and the power will be transmitted by EHV transmission lines, probably at about 500 kV, to the industrial centres such as at Valdez, Anchorage and Fairbanks.

The aggregate power potential of Alaska is in the region of 12,000 MW, but the only installed federal hydro-electric plant is the 30 MW Eklutna station near Anchorage, which was completed in 1954 at a cost of $30 million. Other likely sites for hydro-electric development are the 480 MW Devil Canyon dam on the upper Susitna River, the 40 MW to 65 MW Snettisham project, concerning the tapping of two natural lakes near Juneau, and the 46 MW Bradley Lake dam on the Kenai Peninsula.

Electric Power in Honduras

THE World Bank has approved a loan equivalent to $8·8 million to the Empresa Nacional de Energia Electrica for the development of electric power in Honduras. The loan will help to finance a 27 MW hydro-electric power plant and related transmission facilities. When the project is completed, Honduras for the first time will have a centralised power system, capable of being expanded economically to meet future needs.

Empresa will use the loan for the first stage of a programme to develop the hydro-electric power potential of Lake Yojoa and the Rio Lindo, using the lake as a storage reservoir. The main works to be undertaken consist of dykes on the lake, a three-mile canal, an intake structure and penstocks to bring water from the lake to a power house at Canaveral, in which will be installed two 13,500 kW generating units, and provision will be made for the addition of a third unit. About 175 miles of transmission lines will be built to connect the plant with Tegucigalpa, and with San Pedro Sula and Puerto Cortes and other towns in the north-west.

The Canaveral project is scheduled for completion in late 1963 at a total cost equivalent to $14,750,000.

Uganda's New Radio Link

THE maintenance of essential electricity supplies in remote areas is being facilitated by an automatic radio alarm device introduced by the Uganda Electricity Board. The device, known as a Supply Fail Radio Alarm, gives automatic indication of power interruption and enables Board engineers to proceed quickly to the location of a fault in order to restore supplies. The Radio Alarm consists of a transmitter with a small storage battery kept permanently in a fully charged condition by means of a trickle-charger connected to the mains supply. Should there be any interruption of electricity supplies, a warning signal is originated by the transmitter and beamed to the nearest Uganda Electricity Board district office. The warning, which takes the form of an identifying morse-code signal, is easily recognisable by Elec-

tricity Board radio operators, who can then immediately summon field engineers. The signal is repeated at 90-second intervals until supplies are restored. By using a periodic signal radio frequency, allocation can be used without disruption of normal radio traffic and without the necessity for special receiving equipment. Total installation costs of the device are about £210, but the Board considers that this capital outlay is amply justified by improved consumer service and reduction in loss of revenue as a result of a shorter period of interruption to supplies.

The prototype device which was constructed in the Board's Communications Workshop was installed 15 months ago on a tea estate in the Mityana district, and it has worked so successfully that the Board now plans to install others. Many Uganda Electricity Board offices such as those at Kampala, Bombo, Entebbe, Jinja, Tororo and Iganga maintain a 24 hour service. Radio communication has always been a feature of this service, linking main districts with smaller centres.

Portuguese Electricity

THE annual volume of electricity-supply statistics published by the Portuguese Government for 1959 reveals a steady growth in electricity production and a continuation of the swing-over from thermal to hydro power which we have noted in previous years. In the year under review the total output, at 2,994 GWh, was 12·2% greater than in 1958. Of this total, hydro production, at 2,864 GWh, increased by 14·17%, and thermal production decreased by 17·7%. In the public-supply sector the changeover was even more marked than these figures indicate, for hydro-electric output increased by 14·29% whereas thermal output fell by no less than 55·08%. The total installed capacity in Portugal at the end of 1959 was 1,299 MW, of which 1,033 MW was hydro-electric.

Pakistan's Hydro Progress

DRILLING and survey operations at the Rs. 870 million Kunhar Valley hydro-electric project in Pakistan are proceeding rapidly and work on the project is expected to be undertaken when the final feasibility report is received by the end of this year. Final negotiations for a loan of Rs. 40 million from the Italian Government for the project are also expected to be taken up after the receipt of the report. A request for a loan from the Development Loan Fund of the United States for financing the project is under consideration. Chas T. Man Inc. of the United States have been engaged as consulting engineers by the West Pakistan Water and Power Development Authority, which is executing the Kunhar Valley project. According to present plans, the Kunhar station will have a capacity of 500 MW. There will be three power plants, three tunnels and the necessary transmission facilities. The station will be linked with the West Pakistan grid.

The first phase of the Gomal dam multipurpose project is expected to be completed by next April. The project is estimated to cost Rs. 132·3 million and will bring about 300,000 acres under cultivation and produce 700 million kWh of power. The project consists of the construction of a 400 ft. high dam which will form a reservoir of 1,700,000 acre ft. capacity. The scheme envisages the installation of 12·5 MW capacity in the Adam Kok power house. Another dam could be constructed at Spinikai and in case there is a demand for more power, the new dam could add a further 22 MW. The Yugoslav firm of Energo-Projekt of Belgrade has been working in Pakistan in co-operation with others on this project as well as on the Haro river, Soan river, Muree river, Hub river and on the Kalri Lake hydro station.

The Gujranwala project will enter its second phase of execution aimed at generating a maximum of 13·950 MW from three turbines during the next 14 months. The machinery has been supplied from Yugoslavia. The first generator will be put into commission within ten months and the other two in a further four months' time. The installed capacity of the three units, each having a capacity of 4·6 MW, will be 13·8 MW.

A report on the Hub river project estimates that it will cost Rs. 72·5 million. The scheme consists of a dam creating a lake of 30 sq. miles for irrigation purposes. Two MW of power may be obtained at an extra cost of Rs. 2·5 million.

Bhakra Power House

WORK has been stepped up on the Bhakra power house so that now this is ready for a trial run. One of the five units will be commissioned in November, while the second is scheduled for next February. Each of the remaining three units will be commissioned at three month intervals. The required storage of water in the Gobindsagar reservoir to enable the engineers to commission the power house has already been attained. The five units, each with a capacity of 90 MW, are housed in an earthquake-proof, six-storied building 370 ft. long and 150 ft. high on the left bank of the river Sutlej at the dam site. The right-bank power house with the same capacity will be completed in the Third Five-Year Plan.

The committee of five senior engineers appointed by the Government to inquire into the structural failure of the hoist chamber of the right diversion tunnel at the Bhakra dam, has held that "vibration stresses" caused by the pressure of waters in the tunnel were the real cause of the mishap. Ten persons lost their lives, and the dam galleries and the left-bank power plant were flooded at that time.

El Salvador Guajoyo Scheme

THE World Bank has approved a loan equivalent to $3,840,000 for the expansion of electric power facilities in El Salvador. The loan will finance imported equipment and services for the construction of the Guajoyo 15 MW hydro-electric power plant and associated transmission facilities. The loan has been made to the Comision Ejecutiva Hidroelectrica del Rio Lempa, a semi-autonomous government agency established in 1945 to plan and provide facilities to meet El Salvador's power requirements. It supplies power wholesale to the country's principal distributors of electricity which serve nearly all consumers. The Comision's programme is based on the power potential of the River Lempa system. At present, CEL's only power plant is the Guayabo plant, described in our April 1957 issue, which now has a capacity of 45 MW, and will have a capacity of 60 MW by 1962, some 45 MW of it financed by $15,545,000 of Bank loans made in 1949 and 1959.

The Guajoyo plant will be near the Desague River, a tributary of the Lempa, and will be equipped with one 15 MW turbo-generator. The project also includes a step-up substation, a 20-mile transmission line to connect the plant with the CEL transmission system, and the necessary extension of existing substations. The project is scheduled for completion by early 1963.

Projects in Mysore

ORDERS for three more units of 89 MW each, in addition to the installation of the first two units at the power station of the Sharavati hydro-electric project, are to be placed. According to the present schedule, power will be commissioned from the Sharavati project in December 1962 and when the first two units of 89 MW each will be commissioned.

Tunnel work on the Bhadra project is expected to be completed by 1961 after which further work is to be undertaken. The project is a multipurpose one combining Tungabhadra, Ghataprabha and Bhadra schemes. In the first stage 18 MW will be installed at Munirabad, which will ultimately have a capacity of 36 MW. When all the components of the project are completed, about 1,210,000 acres of land will be brought under irrigation and about 172·5 MW of capacity consisting of 82 MW of firm and 134·3 MW of seasonal capacity will be available.

Turbines for Karadj

THE second of the two Harland-Morgan Smith vertical-shaft Francis turbines for a new power station under construction in Elburz Mountains, near Teheran, Iran, for the Karadj Dam Authority, has been completed by the Harland Engineering Co. Ltd., Alloa, Scotland. Each turbine is rated at 56,000 h.p. at 333 r.p.m. under a head of 482 ft. Under maximum head power production can reach approximately 80,000 h.p. A very wide head range has influenced the adoption of special features in the design of the turbines. Erection on site is taking place under the supervision of a Harland representative.

Morrison-Knudsen International Constructors Inc. are contractors for both dam and power station, and the consulting engineers are Harza Engineering Company International.

Correspondence

Niagara River Flow

To the Editor, WATER POWER

In his article "The American Niagara Project" published in your issue of August 1960, Mr. Ian B. Mackintosh states that the flow of the Niagara River is steady at about 200,000 cusecs. This is true of the long-term average flow, but since unfortunately this is totally irrelevant to the day-by-day operating situation in the case of this river, it is possible that the statement creates an erroneous impression that the Lewiston and Sir Adam Beck stations will produce unvarying outputs.

Two factors combine to make operation of the Niagara plants both in Canada and the United States one of the most complex operating problems likely to be encountered anywhere.

First, the Niagara Diversion Treaty of 1950 between Canada and the United States requires that the minimum flows over the Falls set by it must be maintained at all times, not merely as a daily average. The Falls flow is in fact measured hourly for official purposes by specially appointed agents of each Government. Water in excess of the required amount over the Falls is available for power production, and must be divided between Canada and the United States according to the Treaty. Consequently, continuous knowledge of the river flow is of vital importance.

Second, while the annual average flow of the Niagara River is notably constant, this average conceals a marked seasonal pattern in flow of the order of $\pm$15,000 cusecs, generally lowest in February and highest in June, and a still more marked variation in hourly flows due to the sensitivity of Lake Erie to winds. This in turn is due to the Lake's comparative shallowness—averaging only 65 feet over its 240 miles of length. Lake Erie is in fact almost always, to some degree, in a state of oscillation, and during stormy weather the magnitude and period of oscillation are such that the level at the eastern end, out of which the Niagara River begins its short but eventful 36-mile course to Lake Ontario, can change by several feet in a few hours. Since the Niagara River flow is influenced greatly by the above-mentioned changing level in the order of some 20,000 cusecs per foot, such wind seiches on Lake Erie can thus result in changes of $\pm$60,000 cusecs in the river flow in a matter of hours.

Bearing in mind that it is the *hourly* flow over the Falls that must be maintained, the rapidity with which the diversion to the plants' intakes sometimes needs to be changed will be comprehended. In this connection the pumped-storage facilities will provide valuable cushioning against drastic short-term changes in the main plants' discharge, the measure of the value being that 1,000 cusecs of water at either Lewiston or Sir Adam Beck will produce over 20 megawatts of electric power.

It is foreseen, from the experience already gained by Ontario Hydro through having been for ten years solely responsible for controlling the Falls flow, that the above-mentioned adjustments will prove extremely difficult to effect accurately, partly because of imperfection in river flow prediction and largely because of very real yet not precisely calculable time lags between changes in main- or pumping-plant outputs and resultant intended changes in diversion to maintain correct Falls flow.

To sum up, from the point of view of daily plant operation, the long-term constancy of flow of the Niagara River has no bearing, whereas the short-term changes in river flow and the time lags just referred to compel anticipatory action such as can be imagined would be called for in driving, along a winding road, a car with delayed-action steering.

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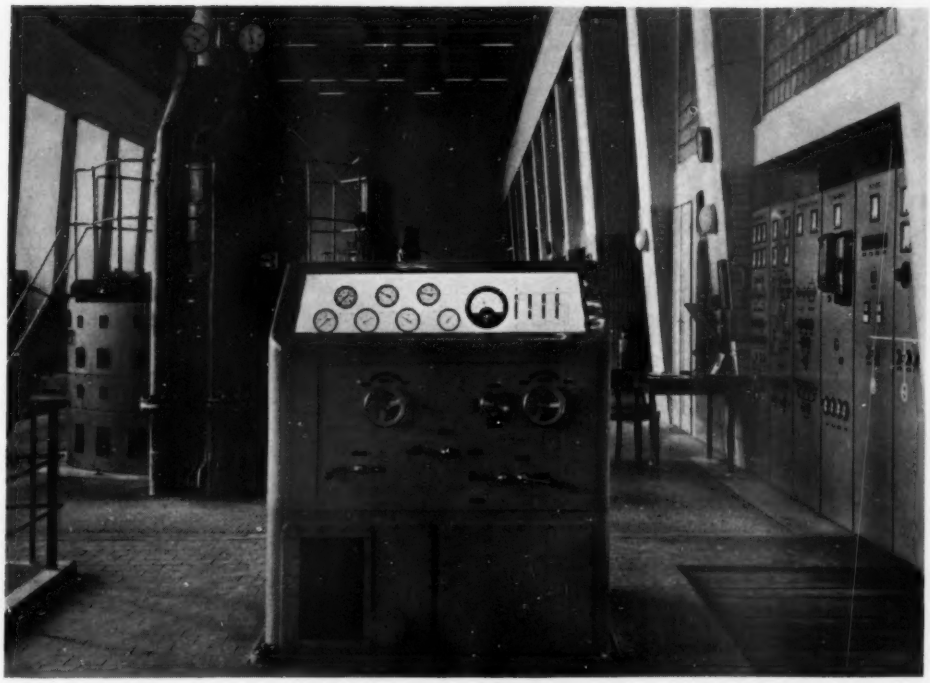

Fig. 12. Interior of Slapy power station; governing gear in foreground

Slapy Power Station

This second article on the Slapy 150 MW station on the Vltava describes the mechanical equipment of the power station, with special reference to the turbines

By Prof. Ing. Dr. MIROSLAV NECHLEBA

PART TWO

THE mechanical installation comprises three Kaplan turbines, each giving a maximum output of 50 MW (67,000 h.p.), and having a discharge capacity of 100 cu. m. per sec. at a head fluctuating between 56 m. and 24 m. The use of Kaplan turbines, which have the relatively high speed of 230·8 r.p.m., has made it possible to reduce the size of the alternator and the dimensions of the power house, as well as the lifting capacity of the travelling crane. It was also much easier to manufacture a Kaplan-type runner than a Francis-type wheel.

Features of the Turbine Design

In accordance with the author's proposition[5], an eight-blade runner, 3,700 mm. in diameter, has been used as shown in Fig. 14. The high head, in fact, requires the use of a greater number of blades in order to diminish the load on the individual blade and to reduce the under-pressure on its suction face so as to avoid cavitation. In the case of high heads, the possibility of distributing the centrifugal force amongst a greater number of blades is also necessary from the point of view of mechanical stress. The diameter of the hub is relatively large, 60% of the outer wheel diameter, due to the necessity of locating the blade-operating mechanism inside the hub (Fig. 17).

The turbine design was checked and corrected by means of model tests carried out at the maker's works under the author's supervision. These tests also permitted measurement of the torque required for regulating the runner blades. These torques are in equilibrium under the operating conditions corresponding to highest efficiency, i.e., at normal speed, so that during the starting period the blades are subjected to heavy torques which have to be overcome by the regulating mechanism. The problem has been solved by the use of right-angled cranks which permit favourable utilisation of the hub space.

A section through the set is given in Fig. 13. The abnormal design of the draft tube is obvious at first sight, its throat having a cylindrical shape instead of the usual conical one. In fact, tests carried out on models revealed the conical shape to be unfavourable

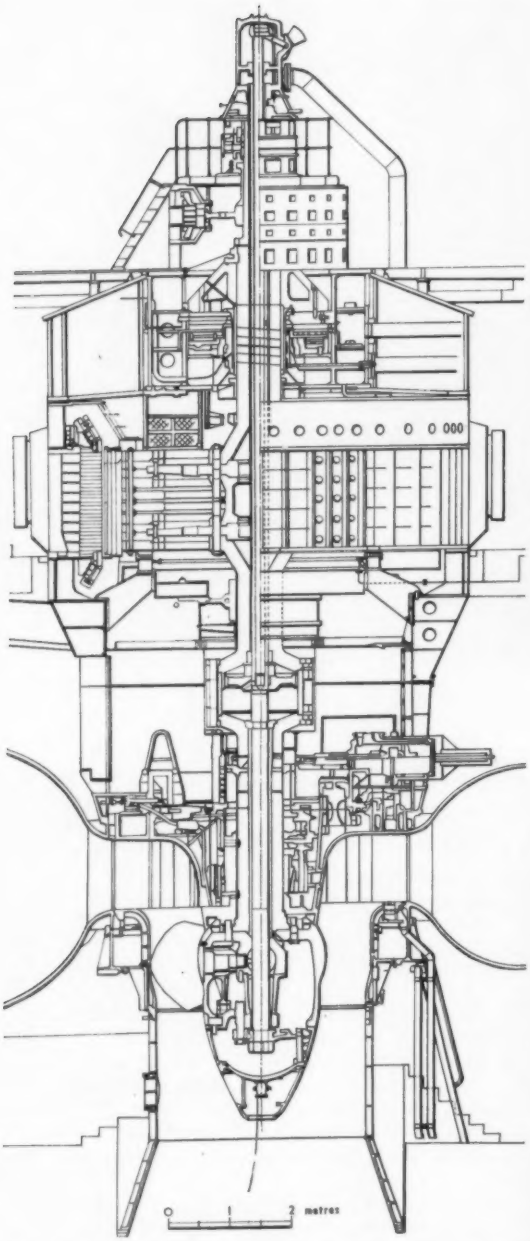

Fig. 13. Section through one of the generating sets in Slapy station

from the standpoint of cavitation, since enlargement of the tube together with the reduction of the runner-hub diameter in the direction of the flow results in too sudden a change of the section and causes the suction column to break up. Observations on the cavitation testing stand[6] showed that by gradually increasing the suction head, clearance cavitation arises mainly at the outer periphery next to the outlet edge of the runner blade. As the suction head increases, the clearance cavitation spreads into the draft tube and finally forms a ring of bubbles at a considerable distance from the runner blades, extending over the whole sec-

Fig. 14. The Kaplan runner in the ČKD Blansko works

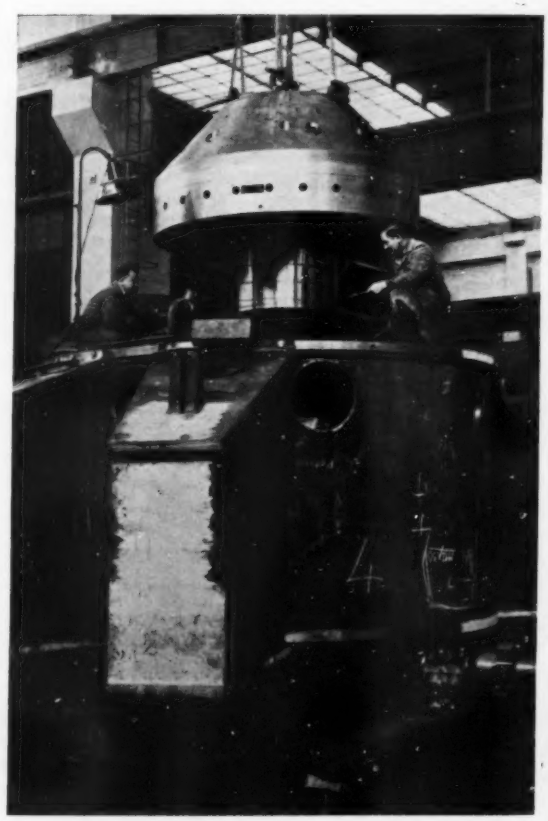

Fig. 15. The thrust bearing in course of assembly

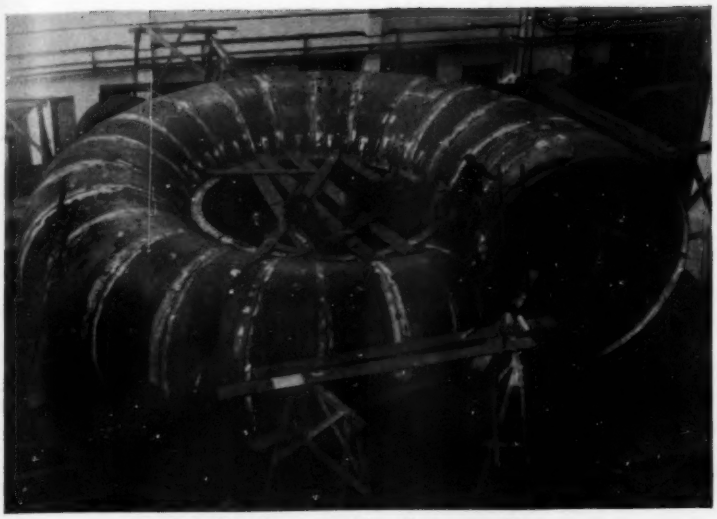

Fig. 16. Works assembly of the scrollcase

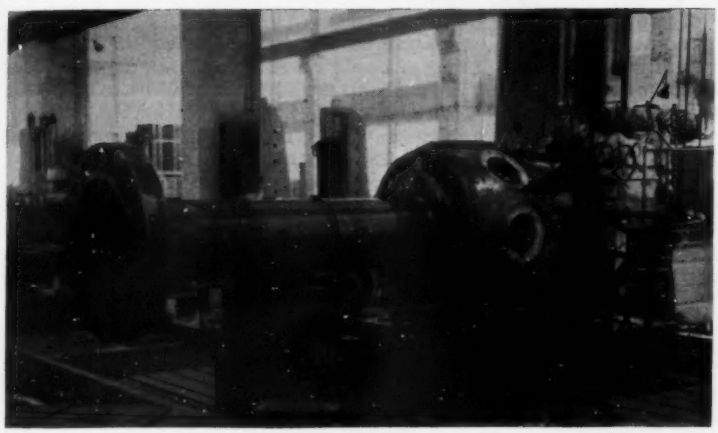

Fig. 17. Machining the turbine shaft and runner hub

tion of the draft tube and preventing continuous flow. During this test, the runner blades remained without cavitation. As a result of the modification to the draft tube just described, the cavitation moved from the suction pipe to the runner, but showed so favourable a Thoma coefficient that it was considered sufficient to install the runner only 4 m. below the lowest tail-water level. In operation, this proved to be correct even at the full head of 56 m.

The runner blades are cast of stainless steel to ensure their resistance to corrosion and erosion by cavitation which attacks particularly those parts situated next to the gap between the blades and the throat ring. The throat ring is made of cast steel and plated with stainless sheet. It is mounted inside a massive cast-steel casing embedded in concrete in which injections are made after hardening to increase its resistance to vibrations caused by flow turbulence and by temporary eddies due to incorrect angles of incidence when the turbine blades are adjusted.

The scrollcase, represented in Fig. 16 while being assembled, is of steel plate and totally embedded in concrete. The intake diameter measures 5 m. and the specific inlet velocity varies between 0·15 and 0·23 according to the head.

The maximum thrust load of the set caused by the weight of the rotating parts and by the hydraulic thrust of the turbine amounts to 800 metric tons. It is transmitted to a segmental-pad thrust bearing of the ČKD-Hofmann design, the segments of which rest upon elastic steel rings so as to ensure a uniform load on all segments. The thrust bearing rests on an upper bracket supported by the alternator stator, as shown in Fig. 13, and is combined with the upper guide bearing. Oil circulation through the coolers and filters is maintained automatically by the bearing itself; for this purpose the supporting head is fitted with radial holes, Fig. 15, operating in the same way as the rotating blades of a centrifugal pump and discharging the oil through a diffuser, Fig. 13, into an upper chamber located inside the welded supporting structure Thence a closed circuit leads the oil through coolers and filters into a lower chamber, from which injection tubes supply oil to the individual segments. Spring-loaded multi-sectional rings, babbitt lined on their working faces, serve for sealing the holes in the rotating runner against back-flow from the diffuser.

Disposition of the Electrical Machines

It is a peculiarity of the design of this set that the auxiliary alternator, together with its exciter, is located directly on the shaft of the main set, whereas the exciter of the main alternator is arranged separately. Irrespective of network disturbances, this auxiliary alternator provides the current for all the electrically driven auxiliaries, including the governor-oil pumping set, the gland-leakage pumps, and the oil pump for the lower alternator bearing. This alternator and the combinator head are the only components that protrude from the floor of the power station (Fig. 12).

The other parts of the turbine are of normal design. The guide vanes are operated by means of a control ring operated by two oil servomotors built into the turbine pit. Simultaneously, the control ring operates aerating valves designed to admit air to the turbine space in case of rapid closure of the vanes.

Intake Gates

It is worth while mentioning the equipment of the intakes leading to the turbine penstocks and to the bottom discharge valves, the main component in each intake being a quick-acting drop gate. The gate moves along roller-fitted caterpillars, as shown in Fig. 7. The gate dimensions are $5{\cdot}280 \times 8{\cdot}600$ m. and its weight is 46 tons. Pressure-oil servomotors are used to lift the drop gates. Two pumps are used, operat-

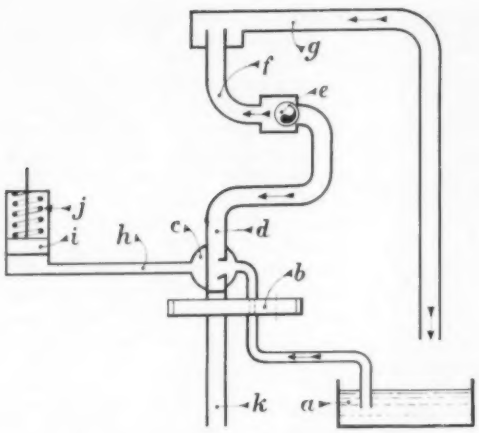

Fig. 18. Hydraulic speed-responsive device

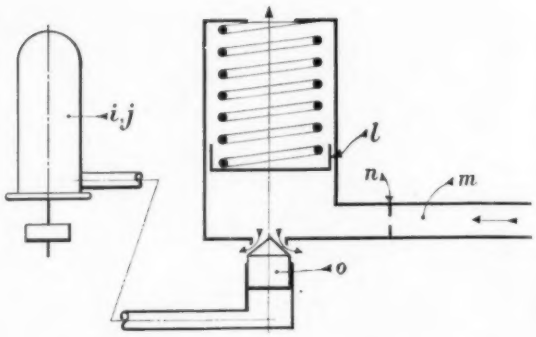

Fig. 19. Control piston and valve system

ing in parallel and designed for a pressure of 80 atm. By pressing a button in the power house the oil is discharged from the servomotors and the gate is closed within 20 sec. Should a serious failure of one of the generating sets occur, the gate closes automatically. The sets are provided with automatic starting and stopping devices, which also control conditions during operation and, in case of a serious failure, automatically stop the set.

Governing System

A hydraulic regulating system equipped with a ČKD-Nechleba hydraulic governor is used for speed control. The speed-responsive device is located upon the turbine itself, being driven by the turbine shaft. Speed variations of the set are converted into variations of the oil pressure which is transmitted to the governor. The governor cabinet can be seen in the foreground in Fig. 12, and the principle of the hydraulic speed-responsive device is shown in the sketch in Fig. 18.

A gear-pump *b* mounted on shaft *k* and driven from the turbine through a toothed gear, draws oil from an auxiliary container *a* and discharges it to a chamber *c*. From this chamber, the oil enters a hollow shaft *d*. This shaft is U-shaped and rotates with the solid shaft *k*, forming an integral part of it. The oil has to force its way against the centrifugal force of a ball *e* which blocks its path. After passing the ball *e*, the oil returns through *f* and *g* into the container *a*. Thus the oil pressure at any moment is determined exactly (or "tuned") by the centrifugal force acting on the ball *e*, irrespective of the viscosity, i.e. of the temperature of the oil. The oil under this controlled or "tuned" pressure is conducted below a piston *i* loaded by a spring *j* and causes the piston to occupy a position exactly in accordance with the turbine speed. It can be proved (Ref. 4, page 455) that the position of the ball *e* remains unchanged by speed variations of the turbine.

Referring now to Fig. 19, measuring piston *i* is so designed that the oil movement within piping *h* is reduced to a negligible value during regulation. Thus, the whole device operates as an ideal inertialess governor. The control piston *l* is operated by pressure oil supplied from the governor-oil accumulator through pipe *m* and diaphragm *n* and discharged through valve *o*. This valve is held to its seat by the "tuned" oil of speed-responsive device *i, j*. Thus, the oil pressure below piston *l* is always adjusted in such a way that the pressure exerted on valve *o* from above equals the force exerted by the "tuned" oil from below. If the valve-seat area equals that upon which the "tuned" oil exerts its pressure, the pressure maintained inside the cylinder below the piston *l* will be exactly equal to the pressure of the "tuned" oil. As the lifting motion of valve *o* amounts only to tenths of a millimetre, the oil movement inside pipe *h*, Fig. 18, is negligible.

As the regulating pulses are transmitted hydraulically the designer can locate the regulator proper in any convenient position. The regulator comprises the control piston, a regulating valve, a temporary follow-up device, and the runner regulator. Usually the governor is located at a suitable place inside the power house next to the instrument panels, together with a luminous diagram and the usual signalling devices (see Fig. 12).

(To be continued)

The River Douro. Two excellent booklets in English have been issued by Hidro-Eléctrica do Douro S.A.R.L., Oporto, Portugal, describing the development of the international and Portuguese sections of this important river. One of these booklets, entitled "River Douro and Tributaries", outlines the physical features of the catchment, and summarises the development and hydro-electric potentialities of the International Douro, the National Douro, and its tributaries the Tâmega, Tua, Sabor, Pacua, Távora and Coa. The other booklet, "International Douro", gives a concise technical description of the three Portuguese stations on this stretch of the river—Miranda, Picote and Bemposta. Both booklets are effectively illustrated.

Rapier Truck Mixers. A new publication by Ransomes and Rapier Limited, 32 Victoria Street, London, illustrates their horizontal drum truck mixers. The advantages claimed in these mixers are a double mixing action, quick loading and unloading, and a special gearbox for quick reversing with automatic check brake.

Hydrology at Helsinki

Following our earlier reports*, we give below summaries of some of the papers of interest in connection with the development of water power, which were presented to the International Association of Scientific Hydrology at the Twelfth General Assembly of the International Union of Geodesy and Geophysics at Helsinki

PART ONE

WATER-POWER engineers are increasingly aware of the need for the most careful hydrological investigation and the most skilful hydrological design possible: as the awareness of the national need for the development of water resources for more than a single purpose increases, so the designers and operators of hydro-electric schemes and, indeed, of electric supply systems dependent on water for cooling, give increasing attention to the quantity and the quality of the available water supplies, and particularly to their variability both in time and in space.

The Helsinki Assembly, although attended chiefly by geodesists, physicists and students of other pure sciences, attracted a large number of engineers whose main concern is the best overall utilisation of the water resources of their areas, and who study their hydrology with much greater care and effort than would have been expected even a dozen years ago. A summary of some of the papers presented at Helsinki will, it is hoped, be of interest to our readers, whether their special fields comprise broad problems of the use of water or whether they are specialists concerned with hydrological detail. The full proceedings of the Helsinki meeting are expected to be available soon from the International Association of Scientific Hydrology (I.A.S.H.).

Major Problems

Dr. H. G. Wilm†, the President of I.A.S.H., in his Presidential Address attempted to define the major problems lying ahead in the field of scientific hydrology. He stressed the competition for land use, and drew attention to the possibility of most forms of land use leading to damage from land erosion, siltation of rivers and the deposition of sediments in reservoirs. Similarly the difficulties of reconciling the competitors for water use are on the increase. Particularly in drought years, experience all over the world shows that domestic demand will compete with industrial or irrigation demand, with water power, navigation, recreation, and with pollution control. The solution to this problem lies in a balance of social, biological, physical, and economic forces, of which the social forces are the most difficult to handle. This is often not fully understood, and the hydrologist may find he has lost an opportunity of putting into practice the most carefully prepared project unless he also takes an active part in the education of the people who use land and water and who make the final decisions, on the basis of social considerations as well as physical, biological and economic studies.

Dr. Wilm specifically mentioned the growth of water shortages, not only in the arid zone but also—and increasingly—in the humid zone. He quoted the example of his own humid State of New York where total precipitation and stream flow are, on average, greatly in excess of present needs, but where the concentration of huge populations, and the prevalence of low stream flow at the time of the highest domestic water demand, call for increasing works of water storage and transport.

In areas where the natural water supply is just sufficient, or just short of requirements, a second major attack on water-supply problems consists of the management of catchment areas, both to increase the total quantity of water and to improve its quality. The I.A.S.H. symposium on forests and water, held in Germany in 1959, enabled research in this field to be discussed*.

Both for humid areas of high population and for the arid zones, desalination will offer prospects for increasing water supplies, and the economic success of this process will depend on the availability of cheap power as well as of the right physical and chemical methods, and of course on the proximity to sources of saline water. Cheap power, however, would equally increase the attractiveness of the transfer of fresh water over great distances.

In addition to the problems of the quantity, distribution and quality of water supplies, I.A.H.S. has since 1957 sponsored the international study of the run-off of dissolved solids. This, together with the silt-transport studies already under way, will provide a measure of how much earth material is transported into the sea.

Surface-Water Studies

I.A.S.H. consists of a number of Commissions (Snow and Ice, Land Erosion, Subterranean Water, and Surface Water) and Committees (Precipitation, Evaporation, Instruments; also Standardisation, and Dissolved Solids), and each of these organised at least one meeting, in the order in which they are enumerated here, during the two weeks' Assembly. There were also two joint symposia, on Droughts and Low Discharges (I.A.S.H. and International Association of Meteorology) and on Tidal Rivers (I.A.S.H. and International Association of Physical Oceanography). Many of the papers presented at all the meetings clearly contained material either of fundamental theo-

* WATER POWER, Vol. 8, No. 12, December 1956, p. 455; Vol. 10, Nos. 2, 3, February, March 1958, pp. 58, 105.
† Bulletin of the International Association of Scientific Hydrology, No. 18, June 1960, p. 5.

* I.A.S.H. Publications Nos 48 and 49, Symposia, Hannoversch-Münden.

retical value or of importance in the study of a limited range of projects (as, for example, glaciological analysis is clearly essential in the investigation of a glacier-fed or snow-fed hydro-power scheme). The Commission discussing problems of the greatest interest to the power engineer, however, is likely to be that of Surface Water, which also took charge of the two joint symposia. However, little attempt was in fact made to establish rigid boundaries separating the Commissions.

The group of papers on droughts and low discharges contained a number of studies which had been prepared for the purpose of forecasts of likely water supplies and had arisen from the need of power authorities. In the first of these, E. Indri, of Italy, showed from past hydrographs of three streams in the Venetian Alps that the variation of discharge during periods of no rain followed, not the exponential decay law usually adopted, but a hyperbolic law of similar appearance.

S. N. Kritsky and M. F. Merkel, of the U.S.S.R., published a statistical study of the tendency of dry years to follow each other. They quote the example of the dry spell of 1933–40, and using the treatment of Markov chains (which H. E. Hurst, working on the Nile, has replaced by a more sensitive technique) arrive at sequential correlation coefficients in the neighbourhood of 0·3. Like Hurst's conclusions, this figure is of vital importance both in the determination of the storage volume of reservoirs required for "over-year" storage, and in the operation of these reservoirs.

W. Laszloffy, of Hungary, arranged for a colleague to present a paper in which he had in his usual masterly way described the empirical (envelope) approach to frequency-duration studies of the low discharges on some Hungarian rivers, large and small, and presented a map of mean specific dry-weather flow.

V. A. Baranoff and L. N. Popoff, of the U.S.S.R., sent in a summary of a paper on the Calculation of the Minimum Run-off in Unexplored Rivers. Their technique consists of formulating empirical formulae correlating the monthly and daily minima with the annual run-off and with the climatogical and other factors in each basin on which measurements have been made, and to apply these formulae to the catchment which, though as yet ungauged, is considered suitable for utilisation.

P. J. Wemelsfelder, of the Netherlands, proposed the use of what he calls the Persistency of River Discharges, justified by an analysis of the rainfall and run-off figures of the Rhine. The analysis of the rainfall at a typical station shows the tendency of successive monthly figures being greater (or less) than the average—i.e. their persistency to be negligible in the case of rainfall, but a similar study of the run-off of the Rhine shows that tendency to be so pronounced as to exclude the possibility of its being fortuitous. The paper shows that most series of months of less than average run-off on the Rhine will be between the limits of length of 3 and 31 months, with the mean at 17 months. The physical reason for this persistency must lie in storage. In view of the length of the persistently low runs, the magnitude of the lake and reservoir storage is insufficient to account for the phenomenon, and soil-moisture and ground-water storages are more likely to provide the large quantities required for the explanation of "persistency."

J. V. Sutcliffe and W. R. Rangeley, of Great Britain, on the other hand, in a paper on the variability of Annual River Flow Related to Rainfall Records, use for their studies two rivers (the Tana in East Africa and the Tongariro in New Zealand) and a long enough unit of time (the year) to avoid the influence of persistency. Using graphical methods, they extended their run-off records by estimating run-off from rainfall, and then applied Gaussian statistics to estimate the lowest annual flows for various periods up to fifty years. The use of what is effectively a run-off coefficient was justified in this case, according to Dr. Sutcliffe's reply to the discussion, but he granted Monsieur Remenieras that in other areas and for shorter durations it might be preferable to deduce the run-off from rainfall by correlating the losses with rainfall and other factors, rather than using a unique linear rainfall/run-off relation.

M. Roche, of France, published a Method of Estimating Low Discharges of Small Frequency, with an Application to the Namorona River, Madagascar. He also extended his run-off records by using the more extensive rainfall records in what appears to be a multiple linear correlation pattern, on a monthly basis.

M. A. Kohler, of the United States of America, presented a paper by R. G. Mann and E. M. Rasmusson on Extended Low-Flow Forecasting Operations on the Mississippi River. In order to serve the important long-distance barge traffic, the River Forecast Centres of the United States Weather Bureau have to collect data on water levels and precipitation and combine these with proposals for reservoir releases to enable the Centres once a week to give a forecast of the channel depths during the ensuing four weeks. The authors, speaking about a part of the Mississippi in Illinois, mention that the station run-off is computed for 533 rainfall-reporting points, and that the unit hydrographs from 208 sub-areas are routed downstream, reach by reach, in accordance with the techniques described by Linsley, Kohler and Paulhus. Not content with this laborious task, the authors have attempted to forecast the most probable flow which would result from the expected precipitation during the ensuing four weeks being superimposed on the conditions prevailing at the time of the forecast. Using some past records for a check of their new procedure, the authors found that the observed precipitation differed from that expected by an average amount of 25%, with a corresponding average error in flow of nearly 40%.

A. Siren, of Finland, described the hydrological causes which led to the occurrence of Low-Discharge Periods in Rivers in Finland.

J. Rodier, of France, the authority on African hydrology, described the Extent of the Exceptional Drought Observed in 1958 in the Equatorial Regions.

M. Visentini, of Italy, speaking of the Great Drought Periods on the Po, dealt with the analysis of the records since 1807 and observed that there had been five drought years before 1870 and 14 after: a sufficiently pronounced change for him to suggest a change in the hydraulic regime of the river.

I. Zsuffa, of Hungary, described the Long-Period Forecasts of Low Flows During Periods of Drought in Hungary. On the basis of the assumption that all drought run-off is, by definition, base flow derived from storage, mostly in Mr. Zsuffa's case ground-

water storage, he has developed diagrams which permit the determination of the flow rate at various times after the beginning of a drought.

E. A. Johnson and H. G. Meginnis, of the U.S.A., in a paper on the Effect of Altering Forest Vegetation on Low Flows of Small Streams, provide evidence of the increased water loss by transpiration of trees, with increased incidence of drought, and the reverse tendency when forests and undergrowth are removed.

E. A. Johnson also presented the paper on Low-Flow Discharges and Plant-Cover Relations on Two Mountain Watersheds in Utah, by R. W. Bailey and O. L. Copeland, of the U.S.A., which contains records of the destruction and rehabilitation of the plant cover of an area whilst the neighbouring area was left intact. The conclusions are that a sound plant cover prevents disastrous flash floods, but causes a reduction in the total volume of annual run-off and of the dry-weather flows.

G. Tison, of Belgium, the son and assistant of the Secretary General of I.A.S.H., had studied the run-off coefficient of numerous catchments in Africa, according to empirical formulae, and now published an improved treatment which takes account of the rate at which rain infiltrates into the soil and is lost to evaporation, so increasing the ground-water reserve on which the flow in dry weather must depend.

S. N. Kritsky and M. F. Menkel, of the U.S.S.R., summarised the Utilisation of Water Resources of Rivers in Arid Zones, with particular reference to the vast arid steppe territories of the south of the U.S.S.R. There 90% of the annual run-off flows down the river in one or two spring months, and must therefore be stored in reservoirs which, because of the great variability of annual run-off and likelihood of protracted droughts, usually contain a storage volume of several years' run-off. Since evaporation losses are of the order of 1 metre per year, the reservoirs must be deep. The design frequency of failure of supply is once in 20 or 30 years for "highly responsible consumers," and once in four years for "auxiliary" consumers.

M. I. Lvovitch, of the U.S.S.R., in his paper on Changes in the River Run-off in Arid Regions under the Influence of Agriculture, reported on experiments which show that, in the spring, the rate of surface run-off from a dry steppe is four to five times that from a field ploughed the previous autumn; with similar, though smaller, ratios for ordinary steppe and forest-steppe.

The Account of Run-off Characteristics in the Arid Regions of the U.S.S.R. in Hydrological Design, by A. I. Tchebotarev and M. S. Protasjev, of the U.S.S.R., mentions that methods of streamflow computations developed in other areas are of no value in arid regions where the variability of streamflow values is very large, the annual streamflow values give a skew plot, and the variations in flow rate follow pronounced cyclic recurrences, both seasonal and over longer periods. Measurement of streamflow must, therefore, be unusually careful and protracted. The influence on run-off of man-made changes, such as variations in land use, is more pronounced in arid than in humid zones.

A. M. Karvatov and O. V. Popov, of the U.S.S.R., in the summary of their paper on Regularities of the Formation of Low Flow, provide a list of researches which is, by any standard, impressive and includes the names of numerous research scientists of the State Hydrological Institute and the Hydrometeorological Service, and presumably others. It is tantalising to reflect on the difficulty of access to the detailed results of this work as compared with the readiness with which, for example, American hydrologists transmit their reports. Perhaps the next General Assembly will make a further contribution towards the construction of bridges between East and West.

(To be concluded)

Ninth Photogrammetry Congress

The Ninth International Congress of Photogrammetry 1960, was held in London during 5-16 September supported by the member societies of 33 countries. Several papers were presented on stereoplotting, mapping, aerial photography, etc., but of direct interest to the hydro-electric engineer were the following two papers:

The Use of Radar Altimetry in the Mapping of a Reservoir (by P. G. Mott). The paper discusses the preparation of a 1:50,000 scale map with 20 ft. contours covering an area of about 1,500 sq. miles on the river Niger above Jebba for a projected reservoir of a multi-purpose scheme, within a very short period of time. It was decided by Hunting Surveys Limited, who were commissioned to produce this map, to base the height control for photogrammetric mapping on data supplied by the Airborne Profile Recorder (APR) aiming to obtain an accuracy of ± 10 ft. at worst, but preferably at ± 5 ft. The results showed that 80% of all check points lay within 5 ft. and 100% within 10 ft. of their true value. There was a saving in time such that ground levelling for controlling the APR profiles took 38 man-weeks instead of the estimated 170 required to provide normal height control for photogrammetric mapping. The total cost of the survey with APR showed a saving of 23% over the estimated cost without APR

Photogrammetric and Geodetic Surveying in the Planning of Hydro-Electric Power Stations (by Einar Rehlung). The author outlines the methods used by the State Power Board of Sweden for photogrammetic and geodetic precedures in the preparation of plans of the water resources for hydro-electric development. Most of the aerial photography has been done by the Geographical Survey Office of Sweden and maps were plotted to a scale of 1:10,000 with a contour interval of 5 m. This method has been mainly applied to the Nordkalott project* for the exploitation of the power resources of the Torne and Kalix rivers as well as other rivers and lakes in that part of the country. Electronic instruments for distance measurement have been introduced, viz. the geodimeter and the tellurometer, in order to make possible the establishment of ground control points as rapidly as required.

The Congress also included an international exhibition of photogrammetrical, aerial-surveying and mapping equipment where British and Continental manufacturers demonstrated their equipment.

* See WATER POWER, February 1960, p. 70.

The Use of a Mean-Value Characteristic in Pipe-Flow Measurements by Current Meters

Simplified numerical methods are described for the evaluation of current-meter measurements of the flow in circular pipes. For meters having nominally identical hydraulic pitch, a "mean-value characteristic" can be used for the evaluation of all results

By F. A. L. WINTERNITZ,* Dipl. Ing., E.T.H., Dr. Tech., A.M.I.Mech.E., A.F.R.Ae.S., V.D.I., and J. N. MANSFIELD,† B.Sc.

THE accurate determination of large flow rates in pipelines of hydraulic power stations and waterworks is of considerable practical importance. On it depends the economic use of water resources as well as the efficient conversion of available hydraulic energy. Irrespective of the method used, the magnitude of such measurements is reflected in their cost, in which production losses during that period must be included. The latter in particular make it imperative to minimise time requirements in the field.

The choice of a suitable method for metering large rates of pipe flow is influenced by the following aspects:—

(a) Established accuracy and consistency
(b) Ease and speed of installation
(c) Time required for measurement
(d) Time required for evaluation.

It is apparent that any reduction in time commensurate with accuracy requirements will constitute a practical improvement of the method in point.

The current-meter technique, long established on the Continent and accepted by the Power Test Codes,[1, 2] has been thus further improved by the design of novel recording equipment[3] and the development of a simplified integration method.[4] Following logically from the latter, a further possible improvement in performance has since been explored: Employing a "mean-value" characteristic, this approach, in conjunction with the NEL recording equipment, has reduced the evaluation of results in the field to a matter of minutes. In consequence, a degree of certainty as regards control over the tests has been achieved, which hitherto could not be attained in current-meter measurements of pipe flow. A further advantage to be noted, in the case of efficiency measurements on hydraulic turbomachines, is the possible investment of time thus gained in increased numbers of flow-rate records where slower associated measurements dictate the overall duration of the tests. This provides a more detailed check on meter performance than is otherwise obtainable.

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Current-Meter Measurement of Pipe Flow

All current meters used in such measurements consist essentially of a propeller-type rotating element which drives a suitably geared mechanical contact. The number of meter revolutions for a chosen time interval is derived from the signals recorded in the same period,

$$n = \frac{N}{t} g = N_t g \qquad \ldots (1)$$

where n = revolutions per unit time,
N = signals recorded in time t,
t = time interval in seconds,
g = signal rate reduction.

The correlation between velocity and meter revolutions is established in still-water towing tank calibrations. Results are conveniently presented as a straight-line equation, several of which may be required for a complete description of meter performance in the velocity range considered,[6]

$$v = k_a n + \Delta v, \qquad n_1 \leqq n \leqq n_2 \qquad \ldots (2)$$

where k_a = hydraulic pitch of the meter, a design characteristic,
$\pm \Delta v$ = residual velocity of the meter, characteristic of meter friction,
n_1, n_2 = limits of counting range for which k_a, Δv = const.

In a presentation of velocity against speed of rotation, the hydraulic pitch k_a represents the slope of a straight line which intersects the velocity axis at $v = \pm \Delta v$. Examples of preferred nominal k_a values: $\frac{1}{8}$, $\frac{1}{4}$, $\frac{1}{2}$, 1. The choice of meter hydraulic pitch is dictated by considerations of varying relative importance; depending on the measurement in point, these include the range of velocities to be covered, the available rate of signal reduction, the limitations of the recording equipment and the time available for individual measurements.

The determination of large pipe flows necessitates the simultaneous use of several current meters in the plane of measurement, their number and positions being specified in the Power Test Codes.[7] A conventional arrangement places the meters at radial positions

in a series of meter rings, each of which bisects an equal sectional area. The number of meters on a ring is at least four, depending on the size of pipe, and is in general equal for each of the rings. Other arrangements may differ in the radial positions chosen. The circular distribution of the meters, however, is always retained, and in the following will be referred to as "meter-rings", an example being shown in Fig. 1. The mean of the velocities measured by the meters of one ring is taken to represent the average velocity for the respective sectional areas and is used as such in both graphical and numerical analysis.

Graphical Analysis

The integral representing the flow through the test section is

$$Q = 2\pi \int_0^R v\, r\, dr \qquad \ldots (3)$$

where Q = flow rate
$v = \bar{v}_r$, mean velocity over annulus of width dr,
r = radial position of measurement,
R = radius of pipe.

The graphical evaluation of Q consists of planimetering presentations of $\bar{v}_r r$ against r and v_r against r^2, technical details being again laid down in the Power Test Codes.[1] The velocities $\bar{v}_r$ which are plotted are the means of the individual meter velocities at the radial positions of the respective rings,

$$\bar{v}_r = \frac{1}{m} \mathrm{i} \sum_1^m v_{\mathrm{i}} \qquad \ldots (4)$$

and hence, with reference to equation (2),

$$\bar{v}_r = \frac{1}{m} \mathrm{i} \sum_1^m (k_{a\mathrm{i}}\, n_{\mathrm{i}} + \Delta v_{\mathrm{i}}) \qquad \ldots (4a)$$

where m = number of meters on the ring.

Since the identical computation is employed in one of the variants of the numerical evaluation method, the conclusions resulting in the following section will also apply to the graphical method of analysis.

Numerical Methods of Integration

Numerical analysis approximates the value of the flow integral as

$$Q^* = \mathrm{i} \sum_1^M \mathrm{d}Q_{\mathrm{i}} = \mathrm{i} \sum_1^M v_{r\mathrm{i}}\, \mathrm{d}A \qquad \ldots (5)$$

where: $\mathrm{d}Q$ = partial flow through sectional area $\mathrm{d}A$,

$\mathrm{d}A = \frac{1}{M}\pi R^2$, sectional area of metering plane,

M = number of sectional areas.

The condition for $Q^* = Q$, i.e. that the mean velocities resulting from the measurements of the meters on the various rings must be equal to the means of the velocity distribution in the various sections $\mathrm{d}A$, resolves itself for a given velocity profile into the correct determination of the radial metering positions. Choice of the conventional arrangement, for instance, with meter rings bisecting the sectional areas $\mathrm{d}A$, results in most practical cases of measurement in overestimation of the flow.[4] Previous work at NEL resulted in a simplified integration technique which constitutes a considerable advance over existing numerical methods with regard to accuracy, flexibility and speed of computation. Table I presents the radial ring positions for various numerical integration rules, those of the novel

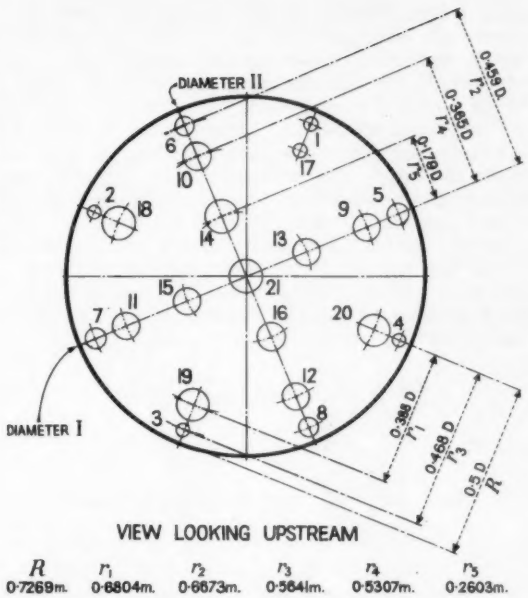

Fig. 1. Example of ring arrangement of current meters

log-linear technique being obtained by ascribing to the flow of a distribution the form

$$v_y = A^* + \mathrm{B}^* \log (y/D) + \mathrm{C}^*(y/D) \qquad \ldots (6)$$

where:

$\mathrm{A}^*, \mathrm{B}^*, \mathrm{C}^*$ = constants with dimensions of velocity,
$y = R - r$, distance of ring from pipe wall,
D = diameter of pipe,

The agreement between the results Q^* of the log-linear numerical integration and the correct values Q was found to be better than $\pm 0{\cdot}3\%$ by comparison with the results of closed integrations of analytical functions representing different velocity profiles[8]. The flow rate follows from

$$Q^* = \pi R^2 \frac{1}{M} \sum_1^M \bar{v}_r \mathrm{i} = \pi R^2 \frac{1}{Mm} \sum_1^M \sum_1^m (k_{a\mathrm{i}}\, n_{\mathrm{i}} + \Delta v_{\mathrm{i}}) \qquad \ldots (7)$$

which is equivalent to

$$Q^* = \pi R^2 \frac{1}{Z} \left\{ \sum_1^Z (k_{a\mathrm{i}}\, n_{\mathrm{i}} + \Delta v_{\mathrm{i}}) \right\} \qquad \ldots (7a)$$

where:

$Z = m.M$, total number of current meters in ringwise distribution,

It follows from equations (7) and (7a) that the numerical evaluation by the log-linear methods can proceed ringwise, as in the computation required for graphical analysis, or yield directly the mean velocity and thus the flow through the test section.

Method of the Mean-Value Characteristic

Modern methods of manufacture ensure a reasonable degree of uniformity in current meters of the

same origin. In general sets rather than individual meters are purchased for large-scale flow measurements, the uniformity being thus improved by batch production. The calibration characteristics of a number of current meters randomly selected from different meter batches are listed in Table II with the values of the hydraulic pitch, grouped according to type of meter and origin. The standard deviation of the mean of each group is less than 1% and could obviously by selective choice, as indicated by asterisks, be considerably reduced. It may be shown, and on this is based the method of the mean-value characteristic, that even without such selection the individual meter characteristics of a set of meters in ringwise distribution may be replaced by their mean,

$$Q^* = \pi R^2 \frac{1}{Z}\left\{\bar{K}_a \, i \sum_1^Z n_1 + \sum_1^Z \Delta v_1\right\} \qquad \ldots (8)$$

where:

$$\bar{K}_a = \frac{1}{Z} i \sum_1^Z k_{a1}, \text{ the mean hydraulic pitch,}$$

and so

$$Q^* = C \, i \sum_1^Z n_1 + D \qquad \ldots (8a)$$

where:

$$C = \pi R^2 \frac{1}{Z^2} i \sum_1^Z k_{a1},$$

$$D = \pi R^2 \frac{1}{Z} i \sum_1^Z \Delta v_1,$$

and C, D are constant in the interval $n_1 \leqq n \leqq n_2$

The condition that k_a and Δv must remain constant for the velocity range of the tests does not in practice prove to be a serious limitation. In general a single equation suffices. It is essential, however, to explore the existing limitations of the method before giving proof of the adequate accuracy obtainable by such an approach. In the following various possible situations are examined.

Nominal Hydraulic Pitch Identical for all Current Meters

In this case equation (8a) applies, the computational procedure being very much simpler than any other numerical method. Results can in general be available within three to five minutes after records have been taken, provided electromagnetic counters are used for meter-signal registration.

Nominal Hydraulic Pitch Identical for the Current Meters on Individual Rings

The flow-rate results from the application of the "mean-value" technique to each individual ring. Hence from equation (7) it follows that:

$$Q^* = \pi R^2 \frac{1}{M} i \sum_1^M \frac{1}{m}\left\{\bar{k}_{a1} \, i \sum_1^m n_1 + i \sum_1^m \Delta v_1\right\} \qquad \ldots (9)$$

where:

$$\bar{k}_{a1} = \frac{1}{m} i \sum_1^m k_{a1}, \text{ mean hydraulic pitch of one ring,}$$

hence

$$Q^* = \pi R^2 \frac{1}{M} \, i \sum_1^m \left\{C_1 \sum_1^m n_1 + D_1\right\} \qquad \ldots (9a)$$

where:

$$C_1 = \frac{1}{m^2} i \sum_1^m k_{a1}$$

$$D_1 = \frac{1}{m} i \sum_1^m \Delta v_1$$

Table I. Distance of Current-Meter Rings from the Pipe Wall for Various Numerical Methods of Analysis

Method and Number of Gauging Points per Diameter		Distance from Pipe Wall R-r in Diameters					
Tangential Rule	6	0·044	0·146	0·296	0·704	0·854	0·956
Tangential Rule	8	0·032 0·677	0·105 0·806	0·194 0·895	0·323 0·968		
Tangential Rule	10	0·026 0·658	0·082 0·774	0·146 0·854	0·226 0·918	0·342 0·974	
Gauss-Sherwood	3 Weight	0·060 5	0·500 8	0·940 5			
Gauss-Sherwood	4 Weight	0·036 0·1739	0·208 0·3261	0·792 0·3261	0·964 0·1739		
"Log. Linear"	4	0·043	0·290	0·710	0·957		
"Log. Linear"	6	0·032	0·135	0·321	0·679	0·865	0·968
"Log. Linear"	10	0·019 0·639	0·076 0·783	0·153 0·847	0·217 0·924	0·361 0·981	

Conventional Tangential Rules and Log-linear Methods: Mean velocity results as arithmetic mean of individual measurements.

Gauss-Sherwood Methods: Multiply readings by weights and divide sum of products by sum of weights.

TABLE II. HYDRAULIC PITCH CHARACTERISTIC OF DIFFERENT GROUPS OF CURRENT METERS

Meter No.	Diameter [m]	Property of	Nominal k_a [m]	Actual k_a [m]	σ [%]
1	0·05	NEL	0·25	0·250	0·7
2				0·252	
3				0·256	
4				0·254	
5				0·252	
6				0·253*	
7				0·253*	
8				0·253*	
9				0·255	
10				0·253*	
11				0·251	
12				0·251	
13				0·254	
1	0·08	OUTSIDE AGENCY	0·44	0·4444*	0·3
2				0·4428*	
3				0·4461	
4				0·4428*	
5				0·4444*	
1	0·08	NEL	0·25	0·2522	0·7
2				0·2540	
3				0·2528	
4				0·2498	
1	0·125	OUTSIDE AGENCY	0·820	0·8256	0·16
2				0·8233*	
3				0·8233*	
4				0·8239*	
5				0·8216	
6				0·8223	
7				0·8226*	
1	0·120	NEL	0·500	0·5108	0·85
2				0·5178	
3				0·5188	
4				0·5129	

σ = Percentage Standard Deviation

and C_i, D_i are constant for one ring in the interval $n_2 \leqq n \leqq n_1$,

The use of the straightforward mean-value method, equation (8a), is still conveniently possible in this case if the product $g_1 \times \bar{k}_{a1}$ is the same for all rings, that is if the ratio of the rates of signal reductions is inversely proportional to that of the hydraulic pitch for different rings. In such a case the signals per unit time N are summed instead of actual meter revolutions n.

Although ringwise computation of results is somewhat slower than the direct mean-value approach, it still compares favourably in this respect with any other conventional method of evaluation.

CASE OF METER FAILURE

The arrangement of equal numbers of meters on each ring may be upset during a test if one or more meters cease to function. Since the contribution of each ring to the mean hydraulic pitch $\bar{K}_a$ and to the sum of all meter revolutions $\mathrm{i}\sum_{1}^{Z} n_1$ is weighted by the number of meters on the ring, equation (8a) cannot be used without suitable modifications.

No restrictions exist if the evaluation proceeds ringwise, equation (9a), whereby for a ring on which one meter has ceased to function,

$$\bar{k}_{aj} = \frac{1}{m-1}\,\mathrm{i}\sum_{1}^{m-1} k_{a1}$$

$$\sum_{j} n_1 = \mathrm{i}\sum_{1}^{m-1} n_1 \qquad \ldots (10)$$

and hence

$$k_{aj}\sum_{j} n_1 = \frac{1}{m-1}\sum_{1}^{m-1} k_{a1}\sum_{1}^{m-1} n_1$$

If the mean-value characteristic for all meters is to be used, the contributions of the particular ring to the mean hydraulic pitch $\bar{K}_a$ and the total of all meter counts $\sum_{1}^{Z} n_1$ must be suitably weighted

$$\left.\begin{aligned} \bar{k}_{a1} &= \frac{m-1}{m}\,\frac{1}{m-1}\sum_{1}^{m-1} k_{a1} \\ \text{and} \qquad \sum n_1 &= \frac{m}{m-1}\sum_{1}^{m-1} n_1 \end{aligned}\right\} \qquad \ldots (11)$$

TABLE III. PERCENTAGE DEVIATION IN "MEAN-VALUE" RESULTS OBTAINED BY COMPARISON WITH LOG-LINEAR VALUES FOR DIFFERENT CASES OF PIPE-FLOW BY CURRENT METERS

Test Case	Test No.	Arrangement of Meters	Type of Computation	k_{ai}	Mean k_a or $\bar{K}_a$	Standard Deviation as % of $\bar{k}_a$ or $\bar{K}_a$	Mean Velocity m/s	Estimated Error [%]	Actual Error [%]	Velocity Profile	Fig.
I	1	4 Rings, each of 4 meters	Ringwise	0·4444 0·4461 0·4465 0·4494 } Ring I	0·44660	0·47	8·755	−0·004	−0·005	Symmetrical, fully developed pipe flow	3
				0·8397 0·8331 0·8207 0·8184 } Ring II	0·82798	1·22					
				0·8350 0·8300 0·8233 0·8239 } Ring III	0·82805	0·67					
				0·8282 0·8272 0·8331 0·8233 } Ring IV	0·82795	0·49					
I	2	4 Rings each of 4 meters	2 equations only	As above	0·44660	0·47	8·755	−0·004	−0·003	Symmetrical, fully developed pipe flow	3
					0·82799	0·77					
II	1/7 2/2 2/10 2/18 2/25 3/4 3/11 3/16 5/8 6/11	1 Ring of 2 meters plus 1 Ring of 3 meters	Ringwise	0·2489 0·2532 0·2514 0·2512 0·2518	0·25105 0·25147	1·21 0·18	2·1478 2·0521 2·0596 2·0513 2·0684 2·1805 2·1725 2·1483 2·5049 2·5899	−0·009 −0·005 −0·005 −0·005 −0·005 0·000 0·000 −0·005 −0·008 −0·004	−0·013 −0·005 −0·005 0·000 −0·010 −0·004 −0·005 0·000 −0·012 0·008	Slightly asymmetric pipe flow	4
III	2/3 2/8 2/14 2/19 2/22 3/28 3/32 3/34 3/36 3/68	2 rings each of 4 meters	Single equation	0·2540 0·2535 0·2522 0·2521 } Ring I 0·2545 0·2535 0·2567 0·2524 } Ring II	0·25361	0·60	2·3055 2·3052 2·3010 2·2913 2·3020 2·7647 2·7549 2·7533 2·7356 2·7509	+0·043 +0·035 +0·035 +0·035 +0·035 +0·036 +0·040 +0·036 +0·040 +0·029	+0·043 +0·035 +0·039 +0·035 +0·039 +0·039 +0·040 +0·040 +0·040 +0·033	Slightly asymmetric pipe flow	4
IV	11	4 rings each of 4 meters	Ringwise	As Case I	0·44660	0·47	7·1507	−0·013	−0·013	Slightly asymmetric pipe flow	4
					0·82798	1·22					
					0·82805	0·67					
					0·82795	0·49					
IV	11	4 rings each of 4 meters	2 equations only	As in Case I	0·44660	0·47	7·1507	−0·013	−0·012	Slightly asymmetric pipe flow	4
					0·82799	0·77					
V	4/1 7/4 3/1 8/2 5/7 A7/3 9/3 A10/1 2/2 6/7	2 rings of 4 meters and 1 ring of 3 meters	Ringwise	0·5044 0·5080 0·5056 0·4986 } Ring I 0·5018 0·5030 0·5016 0·5026 } Ring II 0·5002 0·5108 0·5006 } Ring III	0·50415 0·50225 0·50387	0·79 0·13 1·19	6·1532 5·8583 5·6834 5·4555 4·4939 3·9898 3·2742 2·8763 1·9331 1·7617	+0·037 +0·051 +0·051 +0·046 +0·045 +0·053 +0·064 +0·056 +0·041 +0·068	+0·026 +0·051 +0·051 +0·044 +0·045 +0·050 +0·061 0·000 +0·036 +0·057	Slightly asymmetric pipe flow	5
VI	1	4 rings each of 4 meters	Ringwise	As in Case I	0·44660	0·47	8·6506	−0·052	−0·052	Distorted	6
					0·82798	1·22					
					0·82805	0·67					
					0·82795	0·49					
VI	2	4 rings each of 4 meters	2 equations only	As in Case I	0·44660	0·47	8·6506	−0·057	−0·052	Distorted	6
					0·82799	0·77					

Although $\bar{K}_a$ can now be determined, the accumulated counts from this ring must be corrected by weighting for every measurement before $\sum_j n_1$ can be added to the sum total of the counts from the other rings. Depending on the computational means available, it may be more convenient to evaluate the results of each ring independently and to determine the rate of flow as their mean, in accordance with equation (9a).

A logically similar adjustment is required if individual meters with a hydraulic pitch different from those of the main set of meters are used. The mean-

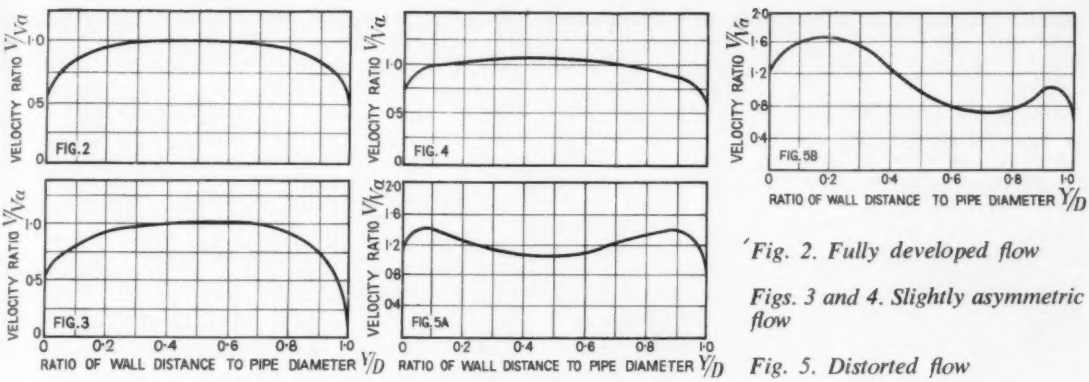

Fig. 2. Fully developed flow

Figs. 3 and 4. Slightly asymmetric flow

Fig. 5. Distorted flow

value computation is greatly simplified in such a case by a suitable rate of signal reduction, as previously outlined, since the only modification then required is the replacement of the meter revolutions per unit time n by the signals N for the respective ring.

It is apparent from the above that the mean-value approach in one of its two possible forms is applicable to most of the practically feasible cases.

Accuracy Considerations

From equation (7a) it follows that for the mean velocity in the case of a log-linear distribution of the current meters in the plane of measurement,

$$\bar{v}_{\text{L.L.}} = \frac{1}{Z}\,\mathrm{i}\sum_{1}^{Z}(k_{ai}n_i + \Delta v_i) \qquad \ldots (12)$$

Equation (12) may be rewritten by use of the following definitions,

$$k_{ai} = \left(\frac{1}{Z}\,\mathrm{i}\sum_{1}^{Z}k_{ai}\right) + \delta\,(k_{ai}) \equiv \bar{K}_a + \delta(k_{ai})$$

$$n_i = \left(\frac{1}{Z}\sum_{1}^{Z}n_i\right) = \delta(n_i) \equiv \bar{n} + \delta(n_i) \quad \ldots (13)$$

$$\Delta v_i = \left(\frac{1}{Z}\sum_{1}^{Z}\Delta v_i\right) + \delta(\Delta v_i) \equiv \overline{\Delta v} + \delta(\Delta v_i)$$

where:

$\pm\delta$ = deviation from the mean, $\therefore \sum_{1}^{Z}\delta = 0$

Hence,

$$\bar{v}_{\text{L.L.}} = \frac{1}{Z}\,\mathrm{i}\sum_{1}^{Z}[\bar{K}a + \delta(k_{ai})][\bar{n} + \delta(n_i)] + [\overline{\Delta v} + \delta(\Delta v_i)]$$

$$= \bar{K}_a \cdot \bar{n} + \overline{\Delta v} + \frac{1}{Z}\sum_{1}^{Z}\delta(k_{ai})\,\delta(n_i) \qquad \ldots (14)$$

$$= \bar{v}_{\text{M.V.}} + \frac{1}{Z}\sum_{1}^{Z}\delta(k_{ai})\,\delta(n_i)$$

where:

$\bar{v}_{\text{M.V.}}$ = mean velocity, result of mean-value approach.

By reference to the log-linear results, the percentage error of the mean-value method may be determined as

$$\epsilon = (\pm)\,\frac{\bar{v}_{\text{L.L.}} - \bar{v}_{\text{M.V.}}}{\bar{v}_{\text{L.L.}}}\,100$$

$$= (\pm)\,\frac{\frac{1}{Z}\sum_{1}^{Z}\delta(k_{ai})\,\delta(n_i)}{\bar{v}_{\text{L.L.}}}\,100[\%] \qquad \ldots (15)$$

If the hydraulic pitch is different for different rings of meters, this becomes

$$\epsilon = (\pm)\,\frac{\frac{1}{Z}\left\{\mathrm{I}\sum_{1}^{m}\delta(k_{a\mathrm{I}})\,\delta(n_i) + \mathrm{II}\sum_{1}^{m}\delta(k_{a\mathrm{I}})\,\delta(n_i) + \ldots\right\}}{\bar{v}_{\text{L.L.}}} \times 100[\%] \quad \ldots (15a)$$

It is evident that for small values of $\delta(k_a)$ and $\delta(n)$ the percentage deviations are likely to be very small, which has been confirmed in several hundred measurements carried out by the current-meter group of the Fluid Mechanics Division of NEL. A number of these are analysed in the following, together with results made available to the authors by outside agencies.

Discussion of Results and Conclusions

Table III presents the values from six test cases, which differed in the velocity distribution at the test section, Figs. 2 to 5, the method of computation and, in parts, in the total number of meters used. For each individual measurement the percentage error was estimated by use of equation (15) or (15a) and compared to the one resulting from the complete evaluation.

The essential conclusions to be drawn from these results are:

(a) Irrespective of the type of velocity distribution, which in one case was strongly asymmetric, or the manner of computation, the actual percentage error of the method of the mean-value characteristic was throughout less than $\pm 0{\cdot}1\,\%$. For the majority of the measurements considered it was less than $\pm 0{\cdot}05\,\%$

(b) Since the recommended log-linear methods used as reference have been shown to be accurate to better than $\pm 0{\cdot}3\,\%$, the mean-value approach may be stated to yield results with an overall accuracy in general considerably better than $\pm 0{\cdot}4\,\%$. It is thus for the most part superior to the standard graphical method of integration.

(c) A comparison of the percentage standard deviations for the meter hydraulic pitch in Tables II and III confirms that the conformity of commercially available current meters is adequate to ensure the above results if used for the mean-value approach.

These numerical values bear out the suitability of the suggested simplified method of pipe-flow integration under a variety of metering conditions which

cover the cases likely to occur in current-meter practice.

The proposed method of the mean-value characteristic has been shown to be universally applicable to the evaluation of results from current-meter measurements of pipe flow, and to be particularly advantageous if used in conjunction with the log-linear arrangement of the current meters and digital recording equipment.

If the meter hydraulic pitch is nominally the same throughout, the mean-value approach is applied to all current meters distributed ringwise in the section of measurement. In the case of different hydraulic pitch for the meters on different rings, the computation proceeds separately for each ring, the mean flow resulting as the mean of the individual ring values. Irrespective of the mode of computation, the speed of evaluation is superior to any other method of pipe-flow integration.

The deviations of the results thus obtained from the corresponding log-linear values is throughout less than $\pm 0{\cdot}1\%$ and for the majority of the measurements considered less that $\pm 0{\cdot}05\%$. The absolute accuracy of the method is estimated to be considerably better than $\pm 0{\cdot}4\%$ and thus in general superior to the standard graphical method of pipe-flow integration.

Acknowledgments

The senior author acknowledges the value of many discussions with Mr. W. H. P. Leslie, in charge of the Electronics Section of the Fluid Mechanics Division, NEL, whose interest in the development of mean-value current-meter recording equipment prompted this investigation. This paper is published by permission of the Director of the National Engineering Laboratory.

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Finland's 400 kV Line in Service

In the article "Designing Low-Cost Transmission Lines" published in our May issue leading design data were given of the 400 kV transmission line, the southern part of which was then under construction in Finland to bring hydro-electric power generated in the north of the country to the main centres of population in the south. This line was brought into service at the end of August and now affords a 758 km. trunk line extending from the Kemi River near the Arctic Circle to Hyvinkää some 55 km. north of Helsinki. At present the line is served by four 400 kV transformer stations—Pirttikoski and Petäjäskoski on the Kemi River, Pikkarala feeding in the power from the Oulu River, and the stepdown station at Hyvinkää. A 400/220 kV station is planned at Alajärvi in central Finland and a 400/110 kV station at Kangasala in southern Finland.

The Pikkarala and Hyvinkää stations are on the ring-bus system. All circuit breakers are of the air-blast type having rupturing capacities of 8,000 to 12,000 MVA, and the power transformers consist of banks of three single-phase autotransformers with a fourth unit as spare.

A number of manufacturers were concerned in supplying the electrical equipment. A 225 MVA transformer bank was supplied by ACEC, Belgium, a 465 MVA and a 375 MVA bank by ASEA, Sweden, and a 420 MVA bank by BBC, Germany. The 400 kV switchgear was built by AEG, Alpha-Nidau, ASEA, BBC, and Sprecher & Schuh, and the instrument transformers by BBC and Sprecher & Schuh. In addition, ELIN, Austria, delivered a 220 kV 54 MVA (transmitted power 225 MVA) three-phase phase-shifting booster transformer to control the power distribution between the 400 kV and 200 kV systems, and ACEC supplied five 60 MVA reactors and ASEA one 70 MVA and two 45 MVA reactors. The design and construction of the transformer stations and of the transmission lines were carried out by Imatran Voima Oy (a State-controllers power company) and its associated company Kemijoki Oy. A feature of the 400 kV line is the use of the guyed portal-type tower pioneered by Imatran Voima Oy and used for the past 30 years on their 110 kV and 220 kV systems. Sweden and USSR have also recently adopted this type of tower for their EHV lines.

"Hydraulic Oils" is a new 74 page handbook published by Wakefield-Dick Industrial Oils Limited, Castrol House, Marylebone Road, London, N.W.1. It includes chapters on fundamental hydraulic principles, hydraulic systems, pumps and components, and hydraulic fluids. The handbook contains 50 illustrations, with graphs and formulae, and may be useful to both engineers or students who are interested in the design, operation and maintenance of hydraulic equipment. It is obtainable free on request to Wakefield-Dick Industrial Oils Limited.

Gland Packings. A new reference book for users of gland packings has recently been published by Crane Packings Limited of Slough, Bucks. The book is very comprehensive and is designed as a work of reference. The contents are so arranged that the factors which determine the selection of a gland packing are dealt with one by one in logical sequence. Copies may be obtained free and postage paid from Crane Packing Limited. Requests are also welcomed from bona fide engineering students.

Fig. 1. Warsak dam seen from downstream

Warsak Hydro-Electric Project

This scheme in north-west Pakistan has been designed and built by Canadian engineers in collaboration with the Government of Pakistan, under the auspices of the Colombo Plan

By T. J. MARTIN, B.Sc.Tech, M.E.I.C., M.ASCE.

PART ONE

THE Warsak project is located near a small village of the same name on the Kabul River, in north-west Pakistan. The valley of the Kabul and the adjacent Khyber Pass are well known to students of history as the traditional routes of invaders of what is now known as West Pakistan. In modern times, the roads and mountain tracks of the area are heavily travelled by the caravans of the various nomadic tribes of the region, and it is not unusual to see a child of eight or ten years trudging along the road with the family caravan, carrying a newly-born lamb or kid slung over his shoulders.

Imagine, therefore, the contrast when, in 1955, the Colombo Plan Administration in Canada decided to construct a $60 million hydro-electric project in this area in conjunction with the Government of Pakistan. Within months of the appointment of H. G. Acres & Co. Ltd., of Niagara Falls, Canada, as consulting engineers for the design and supervision of construction, designs were under way and Angus Robertson Limited, of Montreal, were selected as general civil contractors. Key personnel arrived at the site during the summer of 1955, and in October of that year the first instalment of $9 million worth of modern construction equipment arrived in Pakistan and was put into action.

The interests of the Government of Pakistan in construction were looked after by the Warsak Dam Project Organisation headed by a chief engineer, resident at the site. With its staff of administrators, engineers and labour, the WDPO, as it soon became known, contributed incalculably to the success of the project. Apart from information, guidance and assistance in overcoming such local problems as recruitment of labour and expediting of inland transportation of freight from Karachi to the site, the WDPO was directly responsible for the driving of the south-bank irrigation tunnel, construction of the colony, and many other important features.

The Colombo Plan

A significant trend in world affairs during recent years has been the increased awareness among major powers of the desirability of improving living stan-

dards in under-developed countries. This task has been undertaken realistically and in no small measure by the Colombo Plan Administration. Brainchild of a meeting of the Foreign Ministers of the British Commonwealth of Nations at Colombo in 1950, the Administration has since added many other countries to its original Commonwealth members.

Emphasis within the Administration is on systematically planned long-term development and on the provision of necessary help to the under-developed member countries in such a way as to stimulate self-help. At Warsak, the result of this policy has been joint construction of a major hydro-electric development by united Pakistani and Canadian forces with Canada contributing dollar costs in the form of equipment, material, labour and designs, and with Pakistan underwriting all rupee expenses. In this way, the benefits of the project have been felt in Pakistan ever since construction began, as work with good pay has been available for thousands of local tribesmen. Large numbers of Pakistani have learned trades and applied knowledge which will develop and increase in usefulness to themselves and their country, as development and industrialisation progress.

It is significant that as a stimulus to self-help the entire complement of construction equipment will be handed over to Pakistan in working condition along with the completed project. In this way, it is hoped that the Water and Power Development Authority of Pakistan will be able to utilise this equipment as a unit to construct other large projects.

Description of Project

By far the greater proportion of the 26,000 square miles of drainage area above the dam site is in Afghanistan, and as the site is located only 26 miles downstream from the international boundary, the regulated headwater level of elevation 1,269 ft. was determined in relationship to water levels at the border. The limitations thus imposed on reservoir size, and the selection of 10 ft. as the useful drawdown, restrict the available storage to approximately 1,100 million cu. ft. The project, therefore, must be considered essentially as a run-of-river plant.

The principal features of the project are a mass-concrete overflow-type dam with concrete-lined stilling basin for energy dissipation, a surface-type, totally-enclosed power house containing four units of 40 MW capacity, together with substructure for two additional units, and a three-mile long 10 ft. diameter concrete-lined irrigation tunnel. Water is supplied to the generating units through steel-lined 18 ft. diameter penstock tunnels fed by a common 39 ft. diameter concrete-lined power tunnel with an intake structure separate from, but adjacent to, the dam.

The single-phase main transformers are located along the tailrace deck of the power house whence the leads pass vertically to the switching station on the roof. Initially, a double-circuit tranmission line constructed by Pakistan will take power from Warsak at 132 kV, to connect into the West Pakistan grid. Provision has been made in the switching station for the connection of a second double-circuit line and ultimately a fifth line may be required when units 5 and 6 are installed.

Geology

The project is located in an area of metamorphic schists and gneisses in the Khyber hills of the Safed Koh range. The local formations are quite complex in structure, the principal single feature being a syncline plunging north-east, the axis of which intersects the river downstream from the dam site. The foliation and principal joints in the vicinity of the dam site dip downstream at an angle of 45°.

A considerable amount of exploratory work was carried out, including aerial survey, surface mapping, geophysical survey and exploratory drilling, and advantage was taken of such favourable geological features as presented themselves. In particular, the dam was located on sound and impervious strata of multiple schists which gave much more satisfactory foundation conditions than the adjacent decomposed granite gneisses.

Hydrology

The drainage area of the Kabul River above the dam site is bounded by the Hindu Kush rising to elevations of the order of 20,000 ft., and it is apparent from a study of the river hydrograph that snow melt from these mountains plays an extremely important part in the make-up of river flows. Records of river flows exist for a period of more than 50 years and several well-established features of the hydrograph can be noted. During the periods from October to March, the river flow decreases to a consistent minimum in the region of 5,000 cusecs. When temperatures start to rise in March and April, the river flows also increase, reaching a peak usually in June or July. The summer flood lasts some two months and is followed usually by rapid reductions in flows in August and September.

Due to the absence of lakes in the catchment area and due to its general barrenness, there is little retention of rainwater, and runoff is immediate and large.

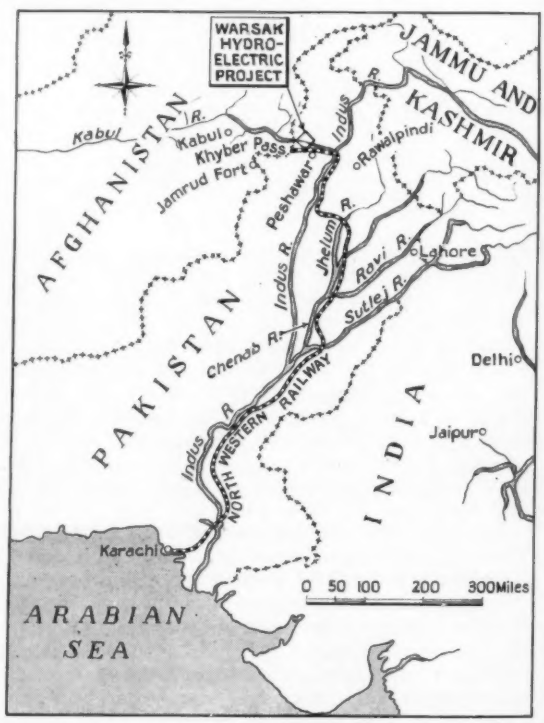


Fig. 2. Location of the Warsak project

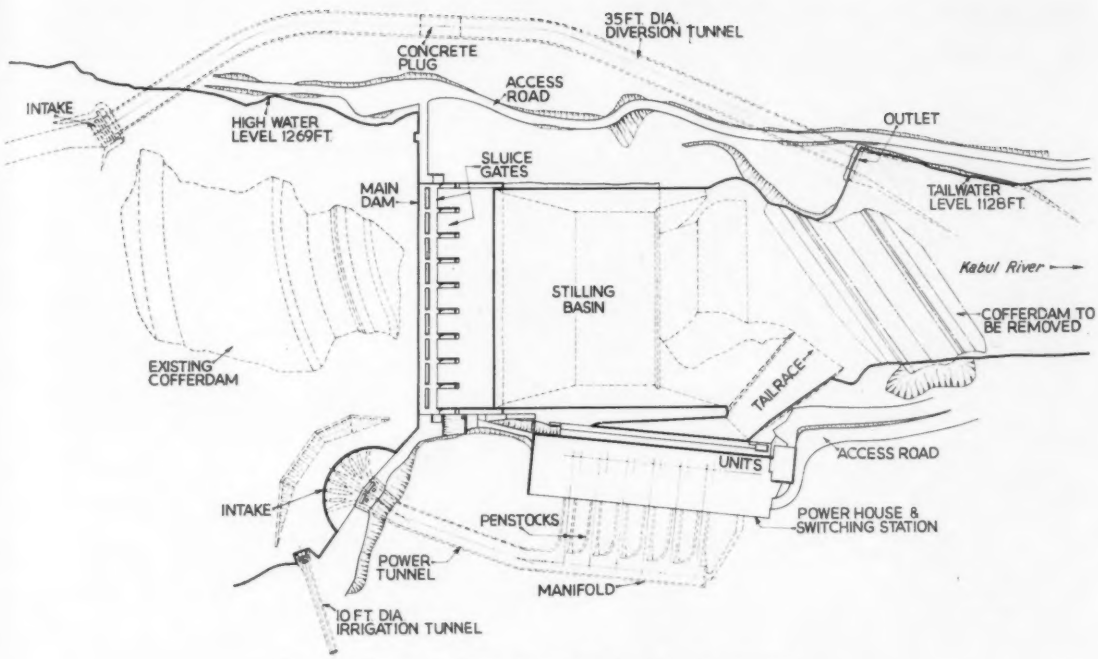


Fig. 3. General arrangement of the Warsak project

Local rainstorms appear as sharp peaks in the hydrograph although, as stated above, the greater proportion of river flow comes from snow melt.

Gauge readings of water level at Warsak are available back to the year 1900, but the instability of the riverbed at the gauging station renders the readings difficult to interpret. During the period of investigation of the project, additional gauges were installed and river-flow metering was carried out. The early water levels were adjusted to allow for changes in the river bed, and a flow-duration curve was prepared on the basis of the estimated discharges. Probability curves were also plotted and various methods of extrapolation were used to assist in selection of the river flows to be used for the design of various parts of the work.

A flood of 540,000 cusecs, having a frequency of occurrence of about once in 10,000 years was finally selected as the basis of design for permanent structures. At this flood, the tailrace deck of the power house will be awash and minor damage may occur, but the consequences will not be disastrous. For the design of temporary structures and diversion facilities, a flood of 200,000 cusecs having a frequency of occurrence of about once in 20 years was selected.

Diversion

The cost of constructing the three 50 ft. diameter lined tunnels necessary for total diversion of the construction design flood of 200,000 cusecs was estimated to be $15 million. It was largely because of this high cost of diversion and the risks involved if the design flood should be exceeded and the works flooded, that H. G. Acres & Co. Ltd. recommended, and the Governments of Pakistan and Canada accepted, a project arrangement incorporating a mass-concrete gravity dam and only partial diversion.

The unwatering scheme finally designed consists of one diversion tunnel and three earth plus rockfill cofferdams, as shown in Fig. 3. The 1,700 ft. long diversion tunnel has an equivalent diameter of 35 ft. Its shape, however, was somewhat distorted to enable the contractor to use the same steel arch form as was required for the 39 ft. diameter power tunnel. The travelling form was manufactured and supplied by Blaw Knox. Below the circular arch the bottom section is approximately elliptical, being made up of 10 ft. 6¾ in. corner radii and an invert having a radius of 39 ft.

Poor rock conditions at the intake portal of the tunnel gave some trouble during excavation, and with the exception of the intake and transition section, the tunnel was driven from the outlet. Throughout the tunnel length, rock quality was not very good, and 8 in. steel sets were used at spacings varying between 4 and 6 ft. Pilot tunnels were driven from the outlet at the level of the steel-set wall plates, then the upper arched section was driven and supported, and finally the bottom section was excavated. Subsequently the pilot tunnels were discontinued and the tunnel arch driven as one face until the excavation was within 100 ft. of breaking through, when pilot tunnels were again driven from both ends to explore the conditions.

The concrete in the invert was placed first of all, using transit mix trucks. Side and arch concrete were placed in a single Pumpcrete operation. A programme of grouting was carried out along the tunnel arch to fill the voids which almost inevitably occur here.

The tunnel passes under the north abutment of the dam and will eventually be blocked by means of a concrete plug located under the abutment and in line with the grout curtain extending the length of the dam. Before the tunnel was completed and put into operation, a grout curtain was established from the tunnel in line with the dam curtain and connecting with it.

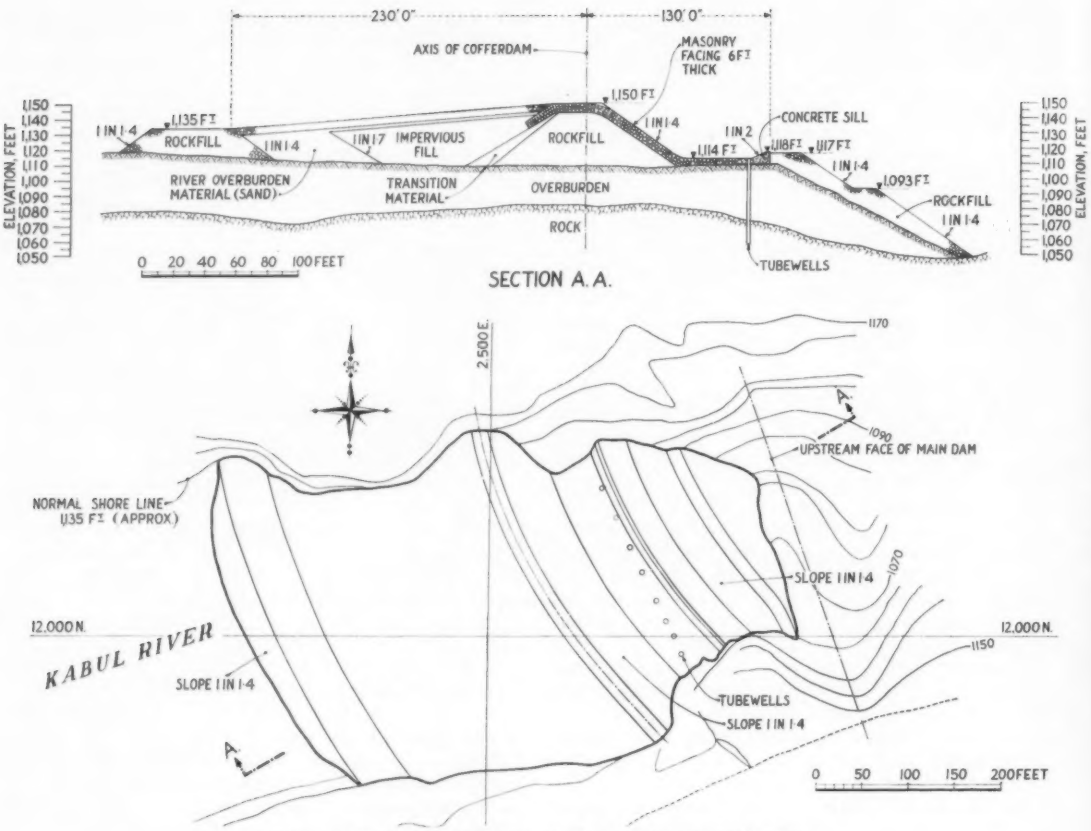


Fig. 4. Plan and sections of the upstream cofferdam

Closure of the tunnel to permit placing of the concrete plug will be by means of two 15 ft. wide by 36 ft. high fixed-roller steel gates located in an intake structure at the upstream portal of the tunnel. The hoists are situated on top of a slender concrete structure rising to elevation 1,257 ft. A rather unusual design feature of the gates is the use of rolled-steel sections for almost the entire gate. The body of the gate consists of 14 in. wide flange beams placed horizontally and reducing in weight towards the top of

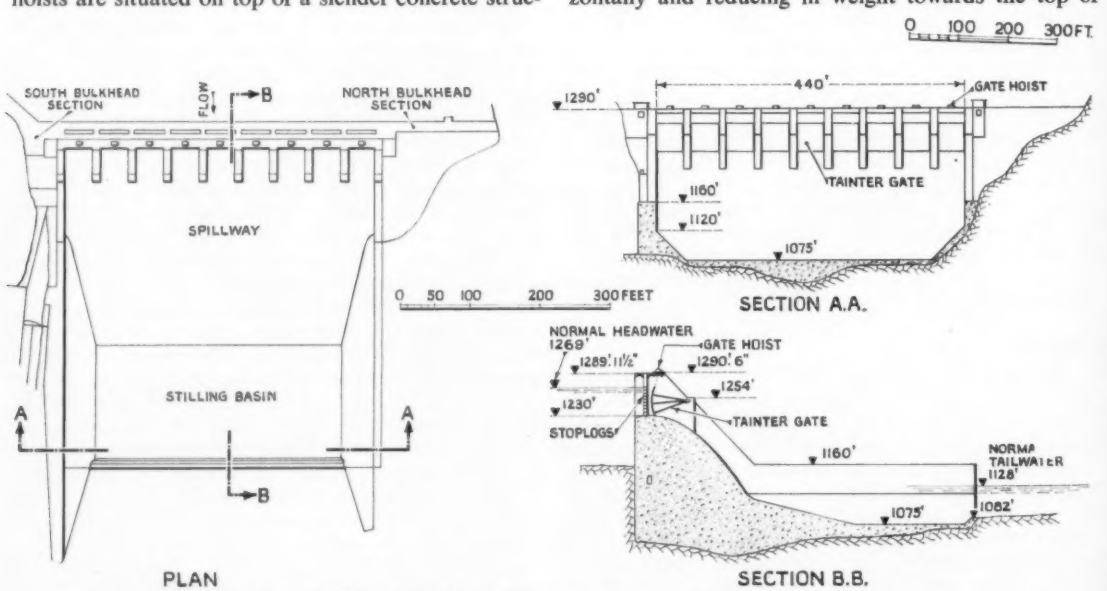


Fig. 5. Elevation of, and sections through, the main dam

Fig. 6. Partially completed dam with floodwater passing through a 150-ft. gap

the gate. Both flanges of each beam are butt-welded continuously across the width of the gate. Shipping requirements necessitated fabrication of each of the gates in three sections, which were then site erected. Each section was provided with machined flanges which were accurately located by fitted bolts installed before final shop alignment. The gates and hoists will be salvaged after the tunnel is plugged and sections of the gates will be modified at the site for use at both ends of the irrigation tunnel. The gates and hoists were manufactured by Canadian Vickers Limited.

Excavation and construction of the power house parallel to the river has continued throughout the seasons behind an earth and rockfill cofferdam along the south bank of the river. The cofferdam was built on top of the existing alluvial deposits overlying fissured rock. A grout curtain was established in both the rock and overburden, and both the impervious core of the cofferdam and the grout curtain were effective in reducing seepage into the power-house excavation.

In order to permit the location of the diversion tunnel portals in suitable places without unnecessarily extending the tunnel, the upstream cofferdam was curved in plan and the downstream one was skewed across the river. A typical section through the upstream cofferdam is shown in Fig. 4.

The Main Dam

The dam is of the mass-concrete gravity type, having a central spillway section with a total length of 460 ft. and having bulkhead sections at the north and south ends with lengths of 160 ft. and 30 ft. respectively. The dam has a maximum height of 250 ft.

Headwater levels and discharges are regulated by nine radial spillway gates, each 40 ft. by 40 ft. with their sills at elevation 1,230 ft. The maximum design flood of 540,000 cusecs will result in a headwater level of elevation 1,285 ft. with all gates fully open. The gate hoists and the road bridge spanning the spillway openings are located at elevation 1,290 ft. A concrete-lined stilling basin is connected to the spillway by an inclined apron.

Seepage beneath the dam has been reduced by a grout curtain extending the entire length of the dam and into the rock abutments and extending to a maximum depth of 250 ft. vertically into the rock. Drilling and grouting for this curtain have been carried out from an inspection gallery located near the upstream face of the dam and at elevation 1,135 ft. Access to the gallery is by stair wells at each end of the dam with a separate small tunnel leading to a footpath at the south end. The footpath leads to the tailrace deck of the power house.

Uplift pressures beneath the dam have been relieved by drainage holes penetrating approximately 100 ft. into rock. These holes were also drilled from the gallery. The flow of water from these drains will be led to the downstream face of the dam through a series of nearly horizontal drains on which backwater valves have been provided to prevent a return flow of water into the gallery during high tailwater periods.

No account of this pressure relief has been taken in the design of the dam. Uplift pressures varying linearly from full headwater pressure at the heel to

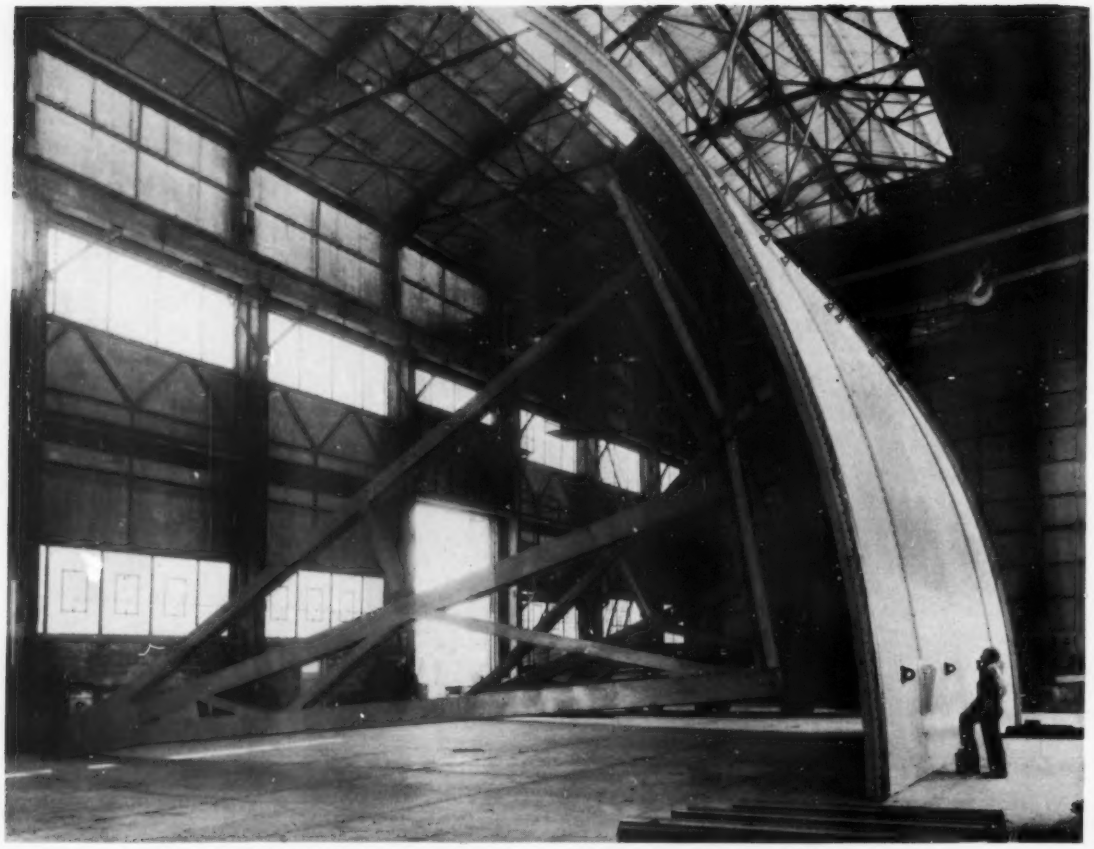


Fig. 7. One of the tainter gates assembled in the Canadian Vickers works

full tailwater pressure at the toe have been included in the design conditions. The pressures have been assumed to act on two-thirds of the base area.

Because of the large amount of sediment transported by the Kabul River, it is expected that the reservoir will accumulate this material. For design purposes, it has been assumed that the deposit will ultimately build up to the spillway crest at elevation 1,230 ft.

The project is located in an area which in the past has experienced fairly heavy earthquake shocks. Earthquake forces were, therefore, considered in the design, and it was decided that the g factor would be assumed to be 0·15. The force was assumed to be applied at a height of 0·4 h from the base.

The loading assumptions described above have been combined with the hydraulic and other loads in a variety of ways to determine the worst loading conditions for the various parts of the structure. Temperature stresses and possible cracking due to restraints on contracting sections of the concrete have been minimised by temperature control of the concrete and its constituents. One method of controlling temperatures within the placed concrete which was found to be particularly effective was the method frequently used by the United States Bureau of Reclamation. This involves pumping cold water through 1 in. diameter thin-walled tubing embedded in the concrete. Consultations were held with experts of the U.S.B.R. and it was decided to cool the lower 30 ft. of the dam using tubes at 2 ft. 6 in. centres both horizontally and vertically. Water was pumped direct from the river as refrigeration was not considered necessary.

The nine radial spillway gates, together with individual hoists and hoist bridge beams, were manufactured by Canadian Vickers Limited (Fig. 7). Stoplog checks are provided in the spillway piers and an interesting feature of the design is the economy made possible by connecting the main tension members supporting the trunnion bearings to the check liners and embedded parts of the stoplog checks. In this way, an economic, single, embedded steel structure transfers the hydraulic loads to the concrete whether gates or stoplogs are used. A single set of stoplogs has been provided so that maintenance work can be carried out in the dry on any single gate. The stoplogs will be handled by a mobile truck crane from the road deck.

Model tests indicated that hydraulic conditions in the stilling basin are best if all spillway gates are open an equal amount. In practice, this ideal condition has been approximated by interlocking the gate hoist controls and operating all hoists from a control console. Incremental discharges are achieved by successively opening gates in 1 ft. intervals; for example, the central gate first opens 1 ft., followed by gates 4 and 6 each to 1 ft., then 3 and 7, and so on until gate 5 opens a second foot, and then the sequence repeats.

(To be continued)

Symposium on Hydraulic Turbine Research

The first symposium on Hydraulic Turbine Research to be held under the auspices of the International Association on Hydraulic Research was held at Nice in September, the arrangements being made by Société Hydrotechnique de France. We present a commentary on some of the most important papers

PART ONE

DURING the Eighth Congress of the International Association for Hydraulic Research in Montreal in August, 1959, a Committee under the chairmanship of Prof. J. W. Daily (Massachussetts Institute of Technology) decided that a "Symposium on Hydraulic Turbine Research" would be valuable, and they accepted an invitation from France to hold it at Nice in 1960. The Symposium was organised by Société Hydrotechnique de France and 138 delegates assembled at Centre Universitaire Mediterranean to discuss 29 papers under three broad headings:—

A. STEADY-STATE OPERATION WITH OR WITHOUT CAVITATION. Chairmen—P. Delattre (France), Prof. L. Borel (Switzerland).

B. FLOW INSTABILITY, REGULATION AND TRANSIENT CONDITIONS. Chairman—Prof. L. J. Hooper (U.S.A.).

C. HYDRAULIC TURBINES, CONSTRUCTION AND OPERATION. Chairmen—Prof. F. N. Scheubel (Germany), M. Fauconnet (Switzerland).

It is interesting to examine the geographical distribution of the papers and the delegates who attended the Symposium.

Paper group	A	B	C		
Author and delegate distribution				Papers	Delegates
France	6	5	6	17	64
Switzerland	–	1	1	2	11
Italy	1	–	–	1	14
Great Britain	1	1	1	3	10
Yugoslavia	1	–	1	2	5
Czechoslovakia	–	1	–	1	2
Poland	–	–	1	1	2
Japan	–	1	–	1	1
Uruguay	1	–	–	1	1
No. papers and delegates	10	9	10	29	110
The remaining delegates came from:—					
Western Europe					11
Eastern Europe					7
Canada and U.S.A.					7
South America					3
					138

In 1958 Société Hydrotechnique de France held their Fifth Hydraulic Conference at Aix-en-Provence, the topic being "Hydraulic Turbines and Pumps." Several papers at Nice therefore reported progress on earlier research and prototype experience, some of which, not unexpectedly, was devoted to tubular pump-turbines for tidal-power projects and their operation in the turbine and pump phases.

With the number of papers of French origin and a strong supporting delegation it was not surprising that this particular topic to some extent dominated the discussion, but nevertheless the high standard which was maintained on other papers dealing with conventional machines and initiation of new research, retained audience interest throughout.

The only report on new laboratories came from Great Britain and gave some justifiable publicity to the model turbine and other testing facilities in the Fluids Mechanics Division at the National Engineering Laboratory at East Kilbride, which are probably the most modern in Europe.

French and British contributions to the discussions were notably constructive in respect of the International Electrotechnical Commission's (Committee TC4) Draft Code (Madrid 1958) which might ultimately allow turbine models to be used in lieu of prototype field acceptance tests. Overall scale effects and the individual losses in reaction turbines were debated but there were no conclusive contributions on these questions vis-a-vis turbines generally. For the more difficult tubular pump-turbines a prototype/model extrapolation method was described.

It is also pleasant to record that a highly original paper from Great Britain by Paul Deriaz on turbine draft-tube phenomena, coupled with three others from France on a similar theme, evoked outstanding interest and discussion on this important instability question, which suggests that future research may produce techniques for dealing with this problem to replace the present unsatisfactory empirical methods.

Four papers relating to cavitation erosion and noise measurements, the influence of air content and protection against damage introduced research recently started in France, Switzerland and Poland, but it is too early to forecast whether significant contributions to current knowledge will result.

Turbine governing and overall system performance, including surge chamber operation on isolated electrical networks, were discussed in four papers, using modern mathematical techniques, operational analysis, and computers for solving multiparameter equations which would otherwise be insoluble.

With this broad survey of the activities of the "First Symposium" to be sponsored by the "Hydraulic Machinery and Equipment Committee" of the International Association, a more detailed and correlated review of the individual papers will be attempted on the following lines.

I. REACTION TURBINES.
1. Model-Testing Techniques and Problems.
2. Scale Effects and Losses.
3. Turbine Waterways.

II. Cavitation.
III. Tubular-Turbine Problems.
IV. Impulse Turbines.
V. Regulation Problems.

The remainder of the present article will be devoted to a summary of the papers on reaction turbines. Subjects II to V will be discussed in a future issue.

MODEL-TESTING TECHNIQUES AND PROBLEMS

Paper A2: "Model Turbine Test Facilities at East Kilbride"—Winternitz (Great Britain)

Hydraulic and aerodynamic research and test facilities available at the National Engineering Laboratory at East Kilbride for industry, long-term research and development, include special equipment for efficiency and cavitation measurements on model turbines up to 20 in. runner diameter. The open- and closed-circuit test rigs feature accuracy, stability, flexibility and instrumentation, and are served by a high-speed digital computer.

Services

(i) *Slave Pumps and Valve Control* giving freedom from head and flow fluctuations, with 300, 475 and 500 kW variable-precision-speed Ward-Leonard drives and (a) electro-mechanical control using tuning-fork frequency standard (accuracy 1 in 10^4); (b) electronic batch counting with crystal oscillator (accuracy 1 in 10^5).

(ii) *Dynamometers.* 150 and 250 h.p. absorption dynamometers which will shortly incorporate the regenerative principle.

(iii) *Water-Treatment Plant* for photographically clear water.

(iv) *Frequency-Timing Standard.* Pulses for digital counting and timing are available continuously throughout the laboratory to an accuracy of 1 in 10^5 with a pulse range of 1 in 10 sec. to 10,000 per second.

Instrumentation

The instrumentation was designed for rig stability and minimised systematic errors. Where the results are to be computer processed, digitised instruments registering on punched tape or cards are used to simplify operation, and eliminate personal errors.

(i) *Flow-Measuring Equipment includes:*—
  (a) 30-ton weigh tank (accuracy ±0·15% with 95% probability).
  (b) 3 Venturi flow meters.
  (c) Propeller meters with electric impulses generated by passage of the blades past a pick-up. This is the preferred method because it gives: (i) minimum scatter; (ii) a linear characteristic over a 20: 1 range with easily digitised recording.
  (d) Frictionless miniature current meters for the variable pressure tunnel.

(ii) *Pressure Measurements.* Digitised multiple water, mercury and rotating-piston manometers with weigh-scale indications are used on the variable-pressure rig. Absolute pressure can be determined within ±0·05% by an automatic weighbeam.

(iii) *Torque Measurement.* The 250 h.p. swinging-frame electric dynamometer on oil-floated trunnions with hydraulically balanced torque reaction is designed for vertical or horizontal operation and has a sensitivity of ±0·01% and with the shaft digitiser and recorder is accurate to ±0·05%.

(iv) *Speed Measurements.* Digital electronic decade counters with gas-filled cathode tubes and battery-operated transistorised counters are used for time and shaft-speed measurements.

(v) *Specific-Gravity Measurements.* Water is corrosion-inhibited with sodium nitrite. The specific gravity varies by about 0·25% and is checked by a continuous through circulation hydrostatic balance giving an accuracy of 1 in 50,000.

(vi) *Gas-Content Measurements* for study of cavitation parameters can maintain the hydraulic-circuit total gas content over a range of ±2%.

Water-Turbine Model-Test Facilities

(i) *Constant- and Variable-Head Test Rigs.* A feature of the variable-pressure tunnel, which is arranged for open- or closed-circuit operation, is the resorber sunk 60 ft. in the ground where air and gas freed in cavitation tests are forced back into solution while the water passes slowly through the high-pressure regions at the bottom of the vessel. At 40°F. the air content can be reduced from 2·5% to 0·4% by volume in two hours. Hydraulic power is supplied by precision-speed-controlled pumps:—

Pumps type	High-head Centrifugal	Low-head axial flow	Booster
Power absorbed h.p.	350	210	180
Characteristics:			
Head ft.	210 80	38 20	300 120
Quantity cusecs	10 30	30 60	10 30

(ii) *Other facilities include:*—
  (a) Closed-circuit television for cavitation observations.
  (b) 35 mm. high-speed camera with optical compensation giving 8,000 frames/sec. and 5-microsec. exposure.
  (c) Programme-data logging equipment.
  (d) Fast-response pneumatic controls for absolute pressure between 0·02 and 4 atmospheres assisted by air pressure and vacuum vessels of 5 cu. ft. capacity.
  (e) Heat exchanger 400,000 B.T.U./hr. to restrict maximum temperature rise to ±5°F. with aerator/deaerator control.
  (f) Multipurpose wind tunnel with 100 h.p. variable-pitch suction or forced-draft fans, delivering 50,000 cu. ft./min. against 10 in. w.g.

Paper C6: "Accuracy in Model Testing"—Winternitz (Great Britain)

Models are used to establish prototype performance and assess qualitative and quantitative behaviour via characteristic parameters. Since absolute geometric, kinetic and dynamic similarity is impossible, equality of controlling parameters is demanded but deviations from similitude are permissible where the physical facts suggest that these are of secondary importance, such as when: (i) Uncontrolled variations occur in the physical properties of the working medium; (ii) The nuclei content in the water changes; (iii) These effects can be estimated.

The fundamental model and prototype efficiency parameters which must be identical are: (a) Discharge and pressure coefficients representing flow and force

distribution; (b) Thoma coefficient if cavitation is involved.

When relaxing similarity conditions second-order criteria must apply to both, otherwise model tests may mask scale effects, but parameters derived from similarity considerations show that the IEC Draft Model Test Code should ensure that similitude deviations are of secondary importance.

(i) *Reynolds Number.* Model and prototype dimensions do not permit Reynolds number equality. Below a critical value between 1 and 2×10^6, where there is a blade boundary-layer transition regime, prototype behaviour cannot be predicted, but above this value performance can be estimated from semi-empirical scaling laws derived from model and field data (see Paper A1). The Reynolds criterion is reflected in the I.E.C. Draft Code which, for Kaplans, gives:—

$H = 4$ m. $D = 0{\cdot}25$ m.
$H = 1$–4 m. $D\sqrt{H} = 0{\cdot}50$ m.

(ii) *Surface Roughness.* Relative roughness affects boundary-layer transition and roughness-cavitation inception. This is not defined by the I.E.C. Code but in aerodynamically smooth surfaces the peaks are submerged in the boundary-layer laminar sublayer, and statistical data, based on roughness height and peak velocity, give the safe maximum Reynolds number R_k as 25. Talysurf records on two random selected guide vanes gave:—

Blade chord length	100 mm.
Radial height	50 mm.
Maximum blade thickness ..	5–6 mm.
Valley peak elevation (max.)	
Normal to flow	0·01 mm.
In flow direction	0·005 mm.
Peak velocity	1·5 m./sec.
Roughness Reynolds No. ..	7·5

Since surface finish could be improved it seems that hydraulically smooth model surface are possible with present production methods.

(iii) *Tip Clearances.* For Kaplan-runner diameters of 4,750 mm. with radial tip clearances of 2·5 mm. the I.E.C. Draft Code requires a minimum gap between model runner blades and casing of 0·13 mm. Bearing play, static and dynamic balance, and transparent materials cannot sustain such fine clearances, but because gap flow losses are small (below 1%), and have inherent scale effects, despite similitude, they are neglected (see Papers A3 and A11).

(iv) *Contour Accuracy.* The effect of small deviations in water-passage contours (see Paper C3) is difficult to estimate, but for Kaplans the permissible I.E.C. tolerances are:—

Blade thickness	±3%
Inclination inner and outer sections	±5%
Blade width	±0·2%

These pose no manufacturing problems and higher standards are possible with automatic computer-controlled machine tools.

(v) *Accuracy of Measurements.* Statistical accuracy assessment based on partial sampling cannot define fixed errors, and estimates rest with the observer aided by careful instrumentation, calibration, measurements and data analysis. In model efficiency tests several measurements are necessary and an accuracy evaluation for NEL equipment is given in Table I.

Automatic instrumentation and recording to eliminate observer errors and an electronic computer for processing test data with more complete sampling and automatic statistical evaluation is undergoing proving tests on the NEL rig.

TABLE I

Measurement	Attainable accuracy	Acceptable Δ	Squared Δ^2
Water density ...	±0·002	±0·01	0·0001
Speed	±0·010	±0·01	0·0001
Torque	±0·050	±0·10	0·0100
Head	±0·010	±0·10	0·0100
Flow	±0·150	±0·15	0·0225
$(\Delta\eta/\eta)^2$ Total			0·0427
Uncertainty level $\Delta\eta/\eta$			±0·21%

Uncertainty intervals below ±0·5% are not easily achieved, and experience at NEL with repeat tests shows the undermentioned results.

Basis	Standard deviation	Precision with 95% confidence limits
Precision ...	±0·15 to ±0·20	±0·30 to ±0·35
Accuracy ...	±0·30 to ±0·35	±0·45 to ±0·50

Paper C3: "Photogrammetric Checking of Model and Prototype Geometrical Similitude"—Bonneval and Vercasson (France)

Checking of geometrical similarity between prototype and model is essential if acceptance is to be based on scale-model performance. Field checking with templates is tedious and is effective only on limited sections without assured similitude between model and prototype templates. In the stereoscopic photogrammetric method developed for Kaplan turbines individual blades are rapidly compared in the shops or on site with each other and with those of the scale model. The system has been extended satisfactorily to the visible faces of Francis turbine blading.

Measurement accuracy is defined by the mean error:—

$$dz = (z/b)\,(z/p)\,da$$

Typical values for blades	Prototype	Model
Viewing-chamber focal length ..	150 mm.	165 mm.
Cover area	130 × 180 mm.	
z = Mean distance from viewpoint to object	3·0 m.	1·0 m.
b = Base length	1·0 m.	0·40 m.
p = Distance from the viewer to the emulsion plane	0·15 m.	0·20 m.
da = Stereoscopic equipment sensitivity	0·01 mm.	0·01 mm.
dz = For industrial and model blades	0·60 mm.	0·12 mm.

The precision is therefore comparable to that on an industrial blade with a similitude ratio of 1 : 5.

The procedure is illustrated for Kaplan, propeller and Francis runners (1–7 m. diameter) and the accuracy relative to IEC/TC4 tolerances shown to be adequate. The advantages claimed are:—

(i) Speedy overall blade shape checking and not merely individual sections.

(ii) Kaplan blade shapes, thickness, curvature and twist can be verified and documented.
(iii) Information procurable when machine is shut down.
(iv) Reference to inaccessible blade or shaft axes is unnecessary.
(v) Low cost relative to runner value.

The method, however, covers only the surfaces, omitting details such as inlet and outlet edges, and requires complex equipment and skilled personnel.

SCALE EFFECTS AND LOSSES

Paper A1: "Scale Effects in the Application of Similitude Laws"—Maggiolo (Uruguay)

Difficulties in accurately measuring high flows suggests that acceptance tests might be made on scale models with prototype efficiency and performance predicted by similitude laws and transposition formulae. The scale coefficients in such formulae, however, result in unacceptable differences in prototype characteristics such as those given below for a 200,000 h.p., 150 r.p.m., 93 m. head turbine starting from a model ($Dm = 544$ mm.).

Scale effect	Method A		Method B
Q = Volumetric efficiency ..	1·0		1·0
H = Hydraulic efficiency ..	1·0		$f(D_p/D_m)$
P = Power conversion ..	1·0		1·0
K = Runner diameter ratio			
D_p/D_m	8·34		8·54
Ratio		1·025	
Efficiency for generated output	0·87	0·89	0·91
Calculated output ..	190,000	200,000	215,000
Ratio	0·950	1·000	1·075

After examining fundamental similitude and scale effects in terms of current calculating methods for: (i) Volumetric losses such as disc friction; (ii) Intake and draft-tube losses; (iii) Turbine-blading hydraulic loss and cavitation; and (iv) Mechanical losses; there is a plea for more exact expressions based on theoretical and experimental loss analysis, with a different approach for Kaplan and Francis turbines. It is also mentioned that model and prototype specific speeds may not be the same.

General mathematical expressions are derived but comparative numerical calculations for model and prototype partial- and full-load efficiencies are not attempted. This would have provided practical support for many of the contentions that prototype field tests will be demanded unless individual and unified scale-effect criteria are produced and their application defined with tolerances.

Paper A3: "Leakage Losses (Kaplan and Propeller Turbines)"—Caseau (France)

Flow between turbine blades includes leakage through a radial clearance between the blades and throat ring, which reduces efficiency. This involves: (i) Flow from the high- to low-pressure zones, thus decreasing the pressure differential between adjacent blades; (ii) Eddies and induced drag. These small losses are lower than those due to viscosity and turbulence, so that leakage-rate variations with pressure difference can be investigated mathematically and model prototype loss similitude criteria deduced via Euler's Theorem leading up to: (a) Thrust exerted on blades; (b) Turbine torque and power; (c) Blade forces; for a leakage distribution between the external envelope and runner in terms of: (i) Entry and exit areas; (ii) Upstream and downstream lateral surfaces; (iii) Unchanged upstream velocities; (iv) Downstream velocity disturbances; (v) Velocity fields; (vi) Thrust variation.

Reynold's number equality and discharge similitude is impossible so that it is best to maintain geometrical similarity and to avoid prototype discharge modifying head losses. This means that:—

$$(x/e)\ (v/U_e)$$

should be minimised by tapering the blade tips to reduce the thickness x where

e = Blade housing clearance
v = Viscosity
U = Peripheral blade velocity
$x/e = 20 - 40$
$U_e/v = 2 \times 10^3$ to 10^4

giving $\Delta p/\rho U^2 = (v/U_e)\ (x/e)\ (1/\rho) < 2 \times 10^2$

Paper A11: "Model Tests for Francis-Turbine Labyrinth Losses"—Viano (Italy)

Further improvement in Francis-turbine efficiencies requires separate loss analyses and examination of labyrinth losses in particular. Results derived from prototype observations are limited in number and range, but their scope has been extended by measurements in small-scale apparatus which allows each parameter to be varied independently by changing the labyrinth: (a) Length, clearance and shape; (b) Upstream pressure; (c) Peripheral speed; and by measuring the two fundamental factors, namely the: (i) Volumetric loss by direct weighing in a given time; (ii) Hydraulic friction losses in terms of the torque applied to the fixed element with water-temperature-rise allowances in the labyrinth passages.

Preliminary leakage-loss curves are derived for given clearances as a function of the: (a) Labyrinth length; (b) Leakage power loss; (c) Hydraulic-friction power loss; (d) Total losses; for different peripheral speeds and pressure differences.

TURBINE WATERWAYS—DRAFT TUBES AND SPIRAL CASINGS

Paper B1: "Francis-Turbine Draft-Tube Flow"—Deriaz (Great Britain)

Internal draft-tube phenomena remained obscure until scale-model testing techniques utilising transparent plastic materials and electronics revealed Francis runner-discharge as a complex velocity distribution which can cause instability around 60% gate opening due to draft-tube conditions. The intensity varies but in critical cases pulsing output and periodic pipeline pressure rises result. The known remedies are not always successful so that it is important that the causes and appropriate curves should be understood.

Thoma explained the phenomena in 1910 in terms of runner-discharge vorticity, but recently high-speed photography coupled with reduced pressures in cavitation rigs disclosed that the vortex core separates from the water mass in a helix moving with a precession motion around the draft-tube axis and instability in the surrounding water mass which rotates in the same direction as the runner. A light vane about 1 in. long in the draft tube can follow rapid periodic flow changes, and pulsing is evident even when the core is absent. As the vortex reaches the draft-tube bend the precession movement continuously modifies the flow path and after a complete cycle returns to

the original form to start again. One channel may provide an easier water exit and lower losses than another, thus varying the bend discharge coefficient according to the precessing vortex position and creating periodic hydraulic resistance changes and pressure pulses at the runner discharge. The net head and runner shaft torque are therefore subjected to periodical variations which stroboscopic observations confirm by showing non-uniform speed and identical pulsation periods. Axial thrust and pipeline pressure are similarly affected.

Model turbines operating at partial gate openings with sufficiently low absolute pressure show that the core enters the bend and collapses with sharp cavitation implosions at the splitter wall. At higher gates the non-precessing straight central core is stable and remains concentric with the draft tube but rotates in the opposite direction to the runner. Instability from other causes occurs occasionally.

The vortex phenomena are explained in terms of efficiency and velocity triangles, with experimental results including pulse frequency and gate opening plotted on unit-speed/discharge contour diagrams.

Precession times are estimated from:—

$$T = 4t = 4L/C_2 = 12L/2\pi nR$$

where t = Flow time from point on blade exit to vortex centre = T/4
L = Distance from point on blade to vortex centre = R to $3R$
n = Runner speed in r.p.s.
R = Runner centre to blade exit-point radius
C_2 = Water velocity = $U_2/3$
U_2 = Peripheral velocity
T = Precession period

giving Precession time $\tau = Tn = 12L/2\pi R$

$\frac{L/R}{\tau}$	$\frac{1{\cdot}5}{3}$	$\frac{3{\cdot}0}{6}$

which agrees with observations, and being independent of linear dimensions, head and specific speed, is the same for model and prototype provided hydraulic similitude is maintained.

Air injection near the runner exit can reduce the intensity of pulsing and vibration under appropriate conditions by transforming a single core into multiple vortices, but the quantity of air required may impair efficiency. Alternatively pressure and power pulsations can be diminished by:—

(i) Stopping vortex rotation before reaching the draft-tube bend with robust radial wall fins or cross pieces located upstream of the elbow but sufficiently below the runner exit not to affect discharge and efficiency.
(ii) Additional depth from runner exit to elbow entry so as to make the disturbance there 180° out of phase with the depression at the runner exit.

Flow instabilities should be removed at their source and adjustment of the relative discharge-velocity direction with gate opening via runner-blade angles, as in Kaplan turbines, would not only eliminate pulsation but also improve part-gate efficiency. This principle can now be applied to Francis units.

Paper B4: "Francis-Turbine Stability"—Campas (France)

Francis turbines are normally stable in the peak efficiency region, but where they must run at low or high loads continuous pressure, speed and power variations may have excessive amplitudes. These may also occur at shutdown. The principal consequences are: (i) Fluctuating electrical and hydraulic phenomena; (ii) Noise; (iii) Vibration and possibly draft-tube lining failure.

Instability phenomena cannot be analysed quantitively, and to study the possibilities of damping, including known empirical methods, measurements of: (i) Pipeline pressure; (ii) Draft-tube pressures at three coplanar points at runner exit and downstream of the elbow by pressure-sensitive devices in the 0–50 c.p.s. range; (iii) Thrust-bearing forces by alternator bracket deflections over the 0–25 c.p.s. range; were systematically recorded on vertical turbines with the following characteristics:

Output	Head	Speed
MW	m.	r.p.m.
85	71	150
66	64·5	150
52	80	187
32	141	375
8·7	117	600
7	69·5	500

Several types of instability may be superimposed and interpretation requires recognition of component phenomena classified below:—

(i) *Light Loads.* Rapid and irregular draft-tube pressure fluctuations without appreciable structural, output, discharge, hydraulic-thrust or pipeline-pressure effects. These are related to annular flow, high velocity gradients near the draft-tube walls and to the almost inert central core which may create intense continuous noise. Operation in this zone should be avoided because of low efficiency.
(ii) *Non-Uniform Velocity and Pressure Fields* in the draft tube having the same rotation as the runner cause periodic pressure oscillations of about 1–2 r.p.s. and ±2–3 m. amplitude near half load. These occur abruptly near 40% gate opening when taking on load, but gradually decrease and vanish in the maximum-efficiency zone. On load reduction they reappear at about 35% gate. This rotating field:—
  (a) May not deform and at given sections is merely displaced, confining the disturbances to the conical approach to the elbow resulting in cyclic forces and rhythmic noise.
  (b) Deforms periodically due to high local whirling velocities varying in position relative to the elbow entry. The reaction may be noticeable throughout the turbine but the effect on hydraulic thrust and pipeline pressure may be small.

  In all cases a fair-sized core exists at the draft-tube centre, but any eccentricity combined with residual rotation causes it to form a helix.
(iii) *Maintained Pressure Oscillations* accompanied by flow, output and hydraulic-thrust variations with impulse head amplitudes of −7 to +9% in the pipeline and −7 to +18% at the draft-tube walls and frequencies of 2–7 c.p.s.
  Oscillograms illustrating these effects, with and without aeration, show that:—
  (a) Appreciable forces develop especially if the draft-tube pressure is small.

(b) Thrust-bearing reaction is attenuated by rotor inertia and may exceed 20% of the weight of the rotating parts, which may occasionally be lifted and dropped suddenly.

The origin is thought to be in the draft tube where axial core volumetric variations modify the discharge with waterhammer reactions maintaining the oscillations, the amplitude and frequency of which are a function of draft-tube shape and runner exit flow. Current investigations include the:—

(a) Conditions necessary for oscillatory phenomena initiation.
(b) Influence of aeration and emulsion injection (waterhammer damping) on efficiency.
(c) Peak pressures associated with the core and pressure attenuation relative to gate opening.
(d) Damping by a small elastic space in the ogive.
(e) Frequency variations in terms of load fluctuations and natural pipeline oscillations.

The oscillations can sometimes be suppressed by a balancing pipe between the runner crown and the draft tube, although natural or forced aeration by injection through the shaft involving reduced efficiency is more usual. More recently the introduction of a fine air/water emulsion through the runner crown or a Fontaine-Peyrin perforated nozzle has proved effective.

(iv) *Heavy and Irregular Impacts* of short duration at high loads having their source in the draft tube or in general turbine flow may range from isolated impulses every 2–3 sec. to sustained oscillations causing structural failures.

High-response pressure probes in draft tubes and spiral casings and strain gauges at draft-tube elbows, splitter walls and stoplog grooves, are being used to ascertain runner exit conditions, their effect on machine components and the optimum amount of and proper location for air or emulsion injection.

(v) *Load Rejection.* Flow instability which may appear during overspeed following load rejection is undesirable because the superposed pressure fluctuations and pipeline waterhammer peaks may exceed those predicted. New phenomena may be associated with overspeed, and analysis of one example shows that:—

(a) After a normal phase, the pressure rise has a second front followed by a series of complex oscillations attributable to short random impacts.
(b) The discharge cessation law is disturbed by rapid and disorganised fluctuations.
(c) Inversion of the hydraulic reaction on the gates is accompanied by ineffective draft-tube aeration.

These observations indicate that separation on the gates or the runner-blade leading edges causes marked entry-angle variations at overspeeds exceeding 40% which may necessitate closure-law modifications.

It is concluded that cases of Francis-turbine instability cannot be resolved without analysis, but sufficient information is available for prosecution of further research.

Paper B6: "Francis Model and Prototype Investigations"—Campas and Giraud (France)

A Francis turbine with the undermentioned characteristics:—

Output	14,350 kW
Design head	125 m.
Test head	138 m.
Speed	500 r.p.m.
Runner outlet diameter	1·330 m.

was tested and compared with 1 : 4·236 scale-model performance, with cavitation similitude maintained where appropriate, in respect of the:—

(i) Efficiency.
(ii) Runner exit, pressure and discharge velocity in magnitude and direction.
(iii) Draft-tube core using photographic methods on the model and resistance gauges on the prototype to indicate the time during which the measuring point is occupied by gaseous masses. In addition records were taken of:—

(a) Wall surface pressure fluctuations via pressure-sensitive probes between 0 and 25 c.p.s. The prototype range was 0–190 c.p.s.

(b) Stabilising Guide Effects on three types mounted at 120° and their influence on efficiency, core formation and motion, and surface pressure fluctuations.

The results show general agreement between model and prototype, but the following might be noted:—

(i) *Discharge.* Consistent variations from −2% to +1·7% over 30–125% gate opening are tentatively explained by minor discrepancies between guide-vane positions.
(ii) *Mean Entry Angle.* Satisfactory correlation.
(iii) *Labyrinth Sealing.* No evidence that leakage losses, which are small anyway, are basically different.
(iv) *Spiral, Guide Apparatus and Runner.* Separation of these losses was not attempted. They are, however, comparable.
(v) *Draft-Tube Losses* are systematically smaller on the model, the ratio varying with gate opening.

Gate opening, mm.	50	65	80	90	100	105	110	125
Loss-coefficient ratio, model prototype	1·02	0·92	0·91	0·90	0·90	0·90	0·90	0·86
Kinetic-energy coefficient, prototype model	0·67	0·61	0·74	0·95	1·03	1·04	1·03	0·78

The increased losses above 115 mm. and below 80 mm. are attributed to greater kinetic energy below prototype runner. These limits correspond to a draft-tube core which did not appear in the model where flow did not conform with cavitation similitude.

(a) *Draft-Tube Entry Velocities and Angles.* Optimum-efficiency-region flows correlate satisfactorily, but at light and heavy loads variations suggest that the central zone, which does not participate in the flow, is more developed at heavy prototype loads.
(b) *Draft-Tube Core.* Agreement exists between core shapes, zones of appearance, and dimensions when cavitation similitude is maintained:—
(i) *Heavy Load.* Core stable, well centred and easily detected in prototype.
(ii) *Light Load.* Core eccentric and corresponds to velocity and pressure fields rotating about the draft-tube axis.

It was established that no gaseous pockets exist outside the core whose dimensions at various radii can be deduced from the time during which the probe is undrowned.

(c) *Draft-Tube Pressures.* The characteristic phenomena appear in model and prototype showing:—
(i) Pressure fluctuation amplitudes (4–5% head) passing through a maximum at about 50 mm. and a minimum near optimum efficiency at 80–95 mm. gate opening.
(ii) A well-defined frequency (1·5–3·0 c.p.s.) at about half load (50 mm.). At heavy loads, pressure-variation frequencies have a random character according to whether the core is central or otherwise.

(d) *Stabilising Guides* are ineffective at heavy loads with

central core but at light loads the displaced rotating field is associated with scattered bubble groups:—

(i) Periodic pressure fluctuations are appreciably diminished in amplitude without having much influence on other operating regimes.

(ii) Model efficiency improvement but the prototype shows a reduction of about 1% at 50 mm. and coincidence at 100 mm. gate.

This lack of correlation might be attributed to strong cavitation behind the prototype guides, which was not evident in the model.

Model and prototype, therefore, show overall agreement of various phenomena with some unexplained deviations. These tests and other papers, notable A1, A11, B1 and B4, however, suggest that methodical model and prototype research with appropriate instrumentation for draft-tube entry-flow surveys, labyrinth and other loss measurements, are warranted.

Paper C2: "Draft-Tube Elbow Surface Pressures and Boundary-Layer Air Admission"—Bayeux and Cavaille (France)

Draft-tube inlet-velocity distributions are usually non-uniform and for higher efficiencies the effects on straight and curved sections are important. Systematic aerodynamic velocity and pressure measurements were made at the diffuser walls and in the cylindrical entry section with woollen threads for velocity distributions, which were: (i) Uniform; (ii) Convex with maximum velocity at the centre; (iii) Concave with minimum at the centre and higher velocities near the walls.

The resultant flow patterns and modifications produced by blowing air into the elbow boundary layer were compared by stereoscopic photographs, from which it was concluded that:—

(a) Concave velocity distribution is favourable whereas convex characteristics cause strong upstream return currents in the outer part of the elbow.

(b) Bernoulli's law applies for uniform and concave distributions but not for the convex case.

(c) A sudden pressure step occurs as the fluid separates from the wall where braking effects can be overcome by admitting adequate air quantities to the elbow boundary layer, thus increasing diffuser energy recovery.

Wind tunnel tests were made to ascertain the elbow and diffuser (i) longitudinal pressure gradients; (ii) boundary-layer aeration effects; (iii) recovery coefficients.

The flow leaving the runner has an appreciable tangential component when it reaches the draft tube and tests introducing rotational flow will follow.

Paper C9: "Turbine Spiral Casings"—Struma (Jugoslavia)

Francis and Kaplan turbine spiral casings are considered to require further theoretical and experimental study, since hydraulic, structural and economic considerations demand minimum dimensions which introduce increased velocities and hydraulic losses. Design methods involving constant circulation are unrealistic whereas those using constant velocity in each section are considered simpler and more accurate.

(To be continued)

Conference on Fluid Sealing

The British Hydromechanics Research Association is organising an International Conference on Fluid Sealing to be held at Grosvenor Hall, Ashford, Kent, from April 17–19, 1961. Papers are invited from workers in this and related fields, and the following is a synopsis of the topics proposed for discussion:

LIQUID SEALS
- Rotating shafts:
  - Packed glands (stuffing boxes)
  - Radial-face and mechanical seals
  - Lip seals.
- Reciprocating shafts:
  - Packed glands
  - Preformed rubber-based packings
  - "O"-rings and similar seals.

GAS SEALS
- Positive types (e.g. radial face)
- Labyrinth types.

SEALING MATERIALS
- Properties of packings for stuffing boxes
- Properties of rubber-based packings and rings
- Properties of materials for radial-face seals.

MISCELLANEOUS
- Screw and other types of dynamic seals
- Seals for extreme conditions of speed, pressure, temperature, etc.
- Methods of sealing corrosive fluids
- Methods of sealing contaminated fluids
- Sealing of two-phase fluids
- Thin film theory and high rates of shear
- Static seals.

It is hoped that each paper will make a fundamental contribution to the theory of sealing or to a related topic, and that the proceedings will be internationally representative. All enquiries relating to papers should be addressed to Mr. Herbert Stephens, Information Officer, British Hydromechanics Research Association, Harlow, Essex.

The fee (not applicable to authors) for the Conference will be £6 6s. 0d. including a set of papers, and accommodation will cost approximately £6. Those desirous of attending the Conference should communicate with the Secretary of the BHRA at Harlow.

New Plants by Aluminium Limited. Two new plants have been established by Aluminium Limited of Canada, one in Jamaica and one in Trinidad, to produce corrugated aluminium sheet and ancillary goods for the local West Indies market. The alumina is processed from bauxite in Jamaica and smelted into ingot aluminium with the aid of the economic hydroelectric resources of Canada. The ingot aluminium is then fabricated into coil sheet in Canada and returned to Jamaica and Trinidad for final processing into corrugated sheet for the local market.

Book Reviews

F.C.E.C. Handbook 1960–61. Published by the Federation of Civil Engineering Contractors, Romney House, Tufton Street, Westminster, London, S.W.1. 304 pp. Price 12s. 6d. including postage and packing.

The Federation of Civil Engineering Contractors, formed in 1919, forms the employers' side of the Civil Engineering Construction Board for Great Britain which regulates the wages and working conditions of civil engineering operatives. The Federation has agreed jointly with the Institution of Civil Engineers and the Association of Consulting Engineers, the general conditions of contract and forms of tender, agreement and bond for use in connection with works of civil engineering construction, together with a variation of price clause (labour and materials) for use in appropriate cases.

The handbook contains all the main Federation documents including the working rule agreement of the Civil Engineering Construction Conciliation Board. Also included, in alphabetical and sectional lists, are the 690 members of the Federation.

Mechanical Design of Hydro Plants. Technical Report No. 24. Volume 3. Published by The Tennessee Valley Authority, Treasurer's Office, Knoxville, Tennessee. 986 pp. including index. Illus. 9 in. × 2⅛ in. × 6 in. 1960. Price, cloth cover $3·75.

This volume is the sixth of a series of special reports being prepared to cover certain phases of engineering and construction work common to all projects designed for the TVA system. The previous volumes of this report cover (1) Civil and Structural Design and (2) Electrical Design, and this volume explains the engineering work involved, including the switchyards constructed at generating stations.

Regulation of flood flows afforded by the system of dams has enabled the TVA to prevent about $140 million in damages since the closure of the Norris dam in 1936. In addition, benefits in the form of increased land values due to greater security from floods to leveed areas on the lower Ohio and Mississippi rivers are estimated at $150 million.

Power demands far exceeded the hydro potential of the region. Up to June 1958—the completion of the 25-year period—8,671,400 kW generating capacity was installed—2,401,400 kW in 77 hydro units and 6,270,000 kW in 45 steam units. Additional capacity under construction and proposed will increase the nameplate capacity to nearly 12 million kW by 1960, this including 595,000 kW in hydro plants owned by the U.S. Corps of Engineers on the Cumberland river and 425,960 kW in hydro plants owned by the Aluminium Company of America on various tributaries in the Great Smoky Mountains area. Engineering and construction techniques have always been kept abreast and possibly somewhat ahead of contemporary design. At present the world's highest single-lift lock is being built at Wilson dam and the world's largest reversible pump-turbine at Hiwassee dam.

These general data precede detailed accounts of the hydro-electric projects which have been completed. Various phases are studied before making a recommendation as to the feasibility of a project: (1) The extent to which flood control should be included in each project; (2) need for and general features of navigation facilities; (3) power potentialities; (4) health and safety requirements; (5) consideration of site topography and hydrological features; (6) appraisal of features affecting reservoir levels; (7) making preliminary cost estimates for use in seeking authorisation for a scheme; (8) economics or determination of annual costs and annual benefits. The projects are covered under various headings in each case—turbines; governors; generators; oil system; compressed-air system; raw-water system; treated water; sewage disposal; drainage and unwatering; fire protection; service equipment; heating, ventilation and air conditioning.

There are five appendices and a very complete index.

Éléments d'Hydrologie Appliquée (Elements of Applied Hydrology). By G. Réméniéras. Published by Librairie Armand Colin, 103 Boulevard Saint-Michel, Paris 5e. 208 pp., 48 ff. Price 4·50 NF.

This little book does not go deeply into the subject of hydrology, except to briefly expose the principles and essential concepts of the science, as well as to present some characteristic methods of analysis and interpretation as used in current practice. The book has been compiled from the main branches of applied hydrology that the author has taught at the Ecole Nationale du Génie in Paris and they may be divided into two sections. The first deals with the atmosphere and hydrometeorology, natural and artificial precipitation, topographic and thermal characteristics of basins, and evaporation. The second outlines the regime of flows and, in particular, the methods of hydrogramme calculation, the predetermination of maximum floods, and statistical methods of flood frequency. At the end of each chapter a short bibliography directs the reader to further study.

Design of Small Dams. United States Department of the Interior, Bureau of Reclamation. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C., and the Bureau of Reclamation, Denver Federal Center, Denver, Colorado. Attention: 841. 1960. 10½ in. × 8 in. × 1⅜ in. 611 pp. Illus. Price $6·50.

It is the intention of this book to give instructions and procedures for the design of small dams, and generally to act as a guide to safe practices. It provides engineers with the information necessary for the proper design of small dams, it supplies specialised technical knowledge that can readily be used by engineers who have no previous experience in this field, and simplifies design procedures. Only the more common types of dams are discussed—the concrete gravity, the rolled type of earthfill and the rockfill dam. All, excepting only the concrete type erected on pervious foundations, are limited in height to 50 ft. above streambed level; the exception is limited to a height of 20 ft. from headwater to tailwater level.

Chapter I is devoted to the purpose of the development—irrigation, domestic and municipal purposes, power development, flood control, etc.—and then goes on to discuss such matters as mapping, hydrological investigations, quantity estimates, planning reports, tests of feasibility and aesthetic values.

Chapter II deals with flood studies taking into consideration such matters as precipitation data, stream flow, watershed data, a method of computing maximum flood discharge, estimating storm potential, unitgraph principles, triangular hydrograph analysis, and the application of triangular hydrographs.

The third chapter covers the selection of the type of dam, its appearance, statutory restrictions, its purpose and benefit-cost relation. The next chapter deals with foundations and construction materials under such headings as scope of investigations, soil classification, rock classification, surface explorations, subsurface exploratory methods, logging of explorations, and field and laboratory tests.

Other chapters consider earthfill and rockfill dams, concrete gravity dams, spillways, outlet works, maintenance and operation. There are also a number of appendices on such matters as estimating rainfall runoff from soil and cover data, hydraulic computations, structural design data, the construction of embankments, and a good deal of space is given to sample specifications.

It will be gathered that the whole subject is considered in a very thoroughgoing manner and although many authors have taken part in the compilation they all have a succinct style and express themselves extremely well. It should be clearly understood that the book refers to practice in the United States only, although there is no reason why it should not be extended to other countries. There is an excellent index.

Multi-Purpose River Basin Development. Part 2C. Water Resources Development in British Borneo, Federation of Malaya, Indonesia and Thailand. Flood Control Series No. 14. United Nations Publication, obtainable from Sales Section, United Nations Office, Palais des Nations, Geneva, Switzerland. Sales No. 59.IIF.5. Price 14s. stg. or equivalent in other currencies.

The problems encountered by these countries in the development of their water resources range from droughts to devastating floods carrying away the rich top soils to the sea. For this reason, all four are at present adopting modern techniques as a means of deriving the highest economic benefits from their water resources. The difficulties presented in framing development programmes are the lack of basic data, lack of competent technologists, a shortage of foreign exchange and the pressure of the population.

Each country is dealt with in turn but we only propose to touch on those schemes involving the generation of hydro-electric power. In British Borneo a provisional investigation was made in 1950 into the potentialities of the Padas river by the British Aluminium Company. Here a site for a dam is available to provide a storage reservoir 181 sq. km. in area which would sustain a regulated flow of 230 cu. m. per sec. and generate 352 MW of prime power. Although there have been no other investigations of power sites in British Borneo, a suitable potential is believed to exist on the Moyog river to give sufficient capacity to satisfy the power requirements of the Jesselton area.

In the Federation of Malaya the Central Electricity Board operates steam, diesel and some small hydro-electric plants. At present hydro-electric plant accounts for about 85 MW against a total 269 MW, most of which is generated by oil. New generating plant now scheduled for service, or projected, totals 204 MW of which 120 MW will consist of hydro-electricity.

In Indonesia, Sumatra is the most fortunate among the islands in regard to hydro-electric power. According to a 1951 estimate by the Department of Power the total potential amounted to 2·86 million kW. Java is the most developed island in regard to water power. The total installed capacity in 1956 was 185 MW, hydro-electric power playing an important role in the overall supply position. About 75% of the hydro-electric plants are owned by the Government and 25% by private companies. The Djatiluhur power house, now under construction, will contain four 25 MW units directly connected to Francis-type wheels. The dam will impound 3,000 million cu. m. of water and will be 100 m. in height with a crest length of 300 m. The project is to be placed in commercial operation in 1963.

Thailand has many suitable sites for water-power development, none of which has yet been exploited. Yet the load on the electrical system is increasing at the rate of 16% per annum. In view of this situation aid was invoked from the International Bank for Reconstruction and Development and resulted in a loan of $66 million for the construction of the Yanhee scheme. This envisages a concrete gravity arch dam—the Bhumiphol dam—154 m. high and having a crest length of 435 m., capable of impounding about 7 million acre ft. of active water, which will sustain a power station having an ultimate capacity of 560 MW. In addition the Yanhee scheme will provide much needed flood control and irrigation for about 240,000 hectares of land.

Recommendations on Determination of Efficiency of Rotating Electrical Machinery (I.E.C. Publication 34-2, Second edition). International Electrotechnical Commission, 1 rue de Varembé, Geneva. Price Sw. Fr. 8.

This publication gives the losses to be included for the different types of electrical machines, when the efficiency is determined by the method of summation of losses. Appendices give information on the so-called calibrated-motor and retardation methods. The general framework of the second edition remains similar to that of the first edition, the main changes being with regard to the reference temperature, altered to take into account the newer insulating materials, and the addition of clauses dealing with the determination of losses in each of the three following schedules, which state the losses to be included: d.c. motors and generators, polyphase induction motors and induction generators, polyphase synchronous motors and generators.

I.E.C. Publication 121: Recommendation for Commercial Annealed Aluminium Electrical Conductor Wire. First Edition. Published by the Central Office of the I.E.C., 1 rue de Varembé, Geneva, Switzerland. 5 pp. Price 2 Sw. fr. plus postage.

The publication, which has recently been issued, prescribes the physical and mechanical property values of commercial annealed aluminium electrical conductor wire having a diameter greater than 1 mm for international use.

Control of Evaporation Losses

In lakes and pumped-storage reservoirs, where the quantity of water stored has influence on the duration of generation, water losses due to evaporation begin to play a part and have to be considered—particularly if the reservoirs are in a hot sunny country. Laboratory work during the period between the wars showed that a film of cetyl alcohol could be spread over the surface and this would reduce evaporation. This was not put into wide practical use until Mr. W. W. Mansfield, of the Commonwealth Scientific and Industrial Research Organisation (C.S.I.R.O.) of Melbourne, began field trials in 1953 and showed, two years later, that a worthwhile reduction in the rate of evaporation of water could be obtained by monolayers of a substance known as hexadecanol.

Hexadecanol is a long-chain fatty alcohol. When this substance is placed on the surface of the water, the force of adhesion between the hydroxyl group of the molecule and the water is greater than force of cohesion between the alcohol molecules and consequently there is a spread of the alcohol to form a surface film one molecule thick.

Fig. 1. A film of cetyl alcohol spreading across Loch Laggan 54 min. from start of application. The effect of the damped ripples is clearly seen with the surface reflecting the dark background

Methods of Application

Different methods have been devised to apply the alcohol solution to the water surface. It should be noted that impurities and foreign substances tend to restrict the alcohol film from spreading evenly by rendering it inelastic. Wind also has an important effect on the film layer in the distribution of the film as well as breaking it. Some of the methods are listed as follows.

Solvent Application Method. The cetyl alcohol, which is insoluble in water, may be dissolved in a suitable solvent of a straight-chain paraffinic hydrocarbon with a boiling range between 90 and 160°C., such as petrol, white spirit or kerosene. A solution concentration ranging from 2% to 10% will satisfy most conditions. The dosage, when applied in solutions of 1 lb. per gallon, is 3 fluid ounces per acre. It is recommended that the cetyl alcohol solution be applied to the water surface at the windward end, either by spraying from a boat or by drip-feed dispensers on rafts. For the latter, it is good practice to apply the feed below the surface to avoid the nozzle blocking by the evaporation of the solvent.

The Mansfield Process. In cases of smaller reservoirs, the C.S.I.R.O. recommends the Mansfield method. For this, cetyl alcohol of specified quality and registered as SI-RO-SEAL Hexadecanol, is prepared in beads of 2–4 mm. diameter and held on the water surface by a raft furnished with wire-gauge sides of 14-16 meshes per inch. Two pounds of beads are used per raft and one raft is sufficient per acre. This method is widely used in Australia.

Solid Dispersion Method. To treat large surfaces of water, experimenters in the United States have developed a method in which powdered cetyl alcohol is slurried with water and the suspension is pumped on to the surface from a moving boat so that wind action may further spread the monolayer formed from the solid particles. But research done by Price's (Bromborough Limited has shown that the prewetting with water reduces the spreading efficiency.

The C.S.I.R.O. have developed a method whereby

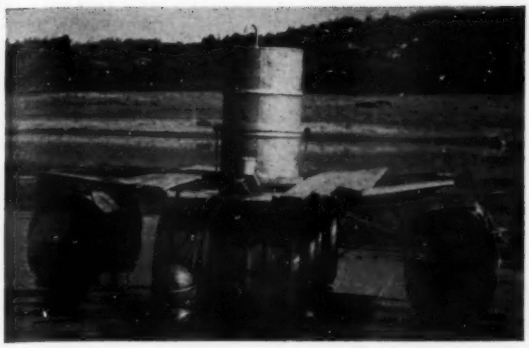


Fig. 2. A floating dispenser used for the trials in Spain. The solution is passed through a rope filter and a ¼ in. needle valve into a plastic tube kept under water by the copper float

the crystalline blocks of alcohol are ground by means of wire brushes and the resultant powder blown on to the surface, with improved results.

Testing the Monolayer

In field work, the spread of the film may be easily observed by its effect of damping ripples on the surface, Fig. 1, but this does not confirm that the monolayer is at the right cohesion pressure for maximum reduction of evaporation. A good testing method is by using piston oils, viz. oleic acid (30 dynes per cm. pressure) and castor oil (17 dynes per cm. pressure). A small drop of oleic acid is carefully applied to the surface. If it does not spread, then the monolayer is near its maximum strength. If the castor oil drop spreads, the monolayer, the pressure of which is about 40 dynes per cm., is insufficiently condensed.

Field Test Trials and Wind Effects

Field tests have been carried out on the Umberumberka reservoir (250-300 acres) in Australia using a commercial cetyl-stearyl alcohol blend. The dosage rate for the first few days was 30 lb. per day and this was subsequently reduced to less than 10 lb. per day. When the wind was light—up to 5 m.p.h.—savings of up to 50% were achieved, but at high wind velocity, the reductions in evaporation were meagre.

Information on the reduction of water evaporation has been gathered from researches carried out by Price's (Bromborough) Limited, in Loch Laggan, Inverness-shire. The trials proved that wind is a more important factor than hitherto thought, and the experiments demonstrate that it is possible to estimate the probable minimum rate at which cetyl alcohol must be applied to maintain an effective film for different wind speeds. Thus the time-consuming effort in establishing the correct dosage for filming a water surface can now be very considerably reduced. Analysis of the results has also brought out a new concept of the effect of wind on the film. It has been found that the film does not move at a constant speed relative to the wind, but progressively accelerates even when the wind speed is steady. Loch Laggan is 11½ miles long, covering 2,500 acres. The section of the loch used for the trials was 7 miles long by ½ mile wide, covering an area of 1,900 acres.

Uniform winds of up to 16 m.p.h. assist in spreading the film provided that the rate of treatment is maintained at the correct level for the wind velocity. Squally winds, however, tend to disperse the film, rendering it less effective.

In another field trial in Spain, cetyl alcohol dissolved in volatile spirit and spread from two large floating dispensers, Fig. 2, saved 35% of the evaporation loss at a cost of 13 pence per 1,000 gallons. When the solvent was changed to kerosene evaporation loss was cut to 31% and the cost was reduced to 7¼ pence per 1,000 gallons.

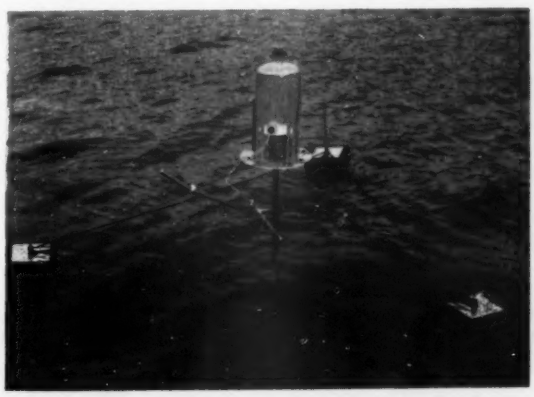


Fig. 3. A 5-litre bottle dispenser mounted on a raft

Acknowledgement

We are indebted to Price's (Bromborough) Limited, Bromborough Pool, New Street, near Birkenhead, for supplying us with information and illustrations to compile this article.

Zeiss Ecomat and Co-ordimat Units

At the photogrammetry exhibition during the Ninth International Congress of Photogrammetry which was held in London last September, Zeiss-Aerotopograph G.m.b.H., Ismaninger Str. 57, Munich 27, West Germany, exhibited two novel machines as listed below:

Ecomat Electromagnetic Recording Unit. In stereoscopic plotting instruments, the co-ordinates of the measuring points are represented on a counter by the number of rotations of the instrument spindles. These co-ordinates have to be transformed into a state co-ordinate system to allow for scale and orientation. Such transformations were usually carried out on simple calculating machines and as there are a vast number of co-ordinates, the transformations become tedious. This led to the design of the Ecomat co-ordinate recording unit for the C8 Stereoplanigraph. This unit consists of three main components. The first is a magnetic counter with pulse generator to give analog-h-digital conversion in units of $^{1}/_{100}$ mm. Once a measuring point has been set, the recording figures are prepared for release through an automatic

typewriter which is the second component. The typewriter is connected to the magnetic counter and receives the command when the operator presses one of two release buttons. The typewriter contains all such features as automatic carriage return and automatic line spacing. There is an interchangeable control plate with 34 rows of 60 slots each, in which control pins can be inserted according to any given scheme. These pins are for programming on punched tape. The third component is a tape punch which consists of an interpreter for transforming the typewriter commands into coded punch-tape symbols and a tape-punch unit. It is intended to design this card punch in such a way that it can be used for automatic plotting of points, the co-ordinate values of which have been stored on the punched cards.

Automatic Co-ordinatograph Co-ordimat. This instrument permits the fully automatic plotting of points, the position of which is given by pairs of rectangular co-ordinates, and is most useful in the field of surveying. Of the two control media, viz. punched tape and punched cards, the latter was chosen as a feed element for ease of filing and sorting. The instrument includes a tracing table with motor-driven measuring spindles capable of travelling in the x and y directions. The read-in equipment is a commercial IBM 024 card punch unit. The instrument has a maximum plotting range of 1,200 mm. by 1,200 mm. with co-ordinate sensing to five digit values from the punched cards. Plotting speed averages about ten points per minute and the accuracy claimed is 0·1 mm.

Whitlock Earthmoving Equipment

We were recently invited to attend the official opening of factory extensions totalling 100,000 sq. ft. at the Great Yeldham, Essex, works of Whitlock Bros. Ltd. The extensions include a fibre-glass manufacturing department, new spares, servicing and stores departments, production offices, power house, washrooms, printing department, and a three-acre assembly shop.

Whitlock Bros. Ltd. were established as agricultural engineers in 1899 and entered the earthmoving field in 1950 with the introduction of the Dinkum Digger. They now claim that they are the only company in the Western Hemisphere manufacturing a complete range of hydraulically operated excavators and shovels.

Advantage has been taken of the extended works facilities to introduce a number of new models to the existing range of equipment. Probably the machine of most interest to contractors engaged on hydro-electric schemes is a new 10-ton dumper, depicted in Fig. 1. It is a four-wheeled machine comprising a two-wheeled tractor unit articulated to the dumper

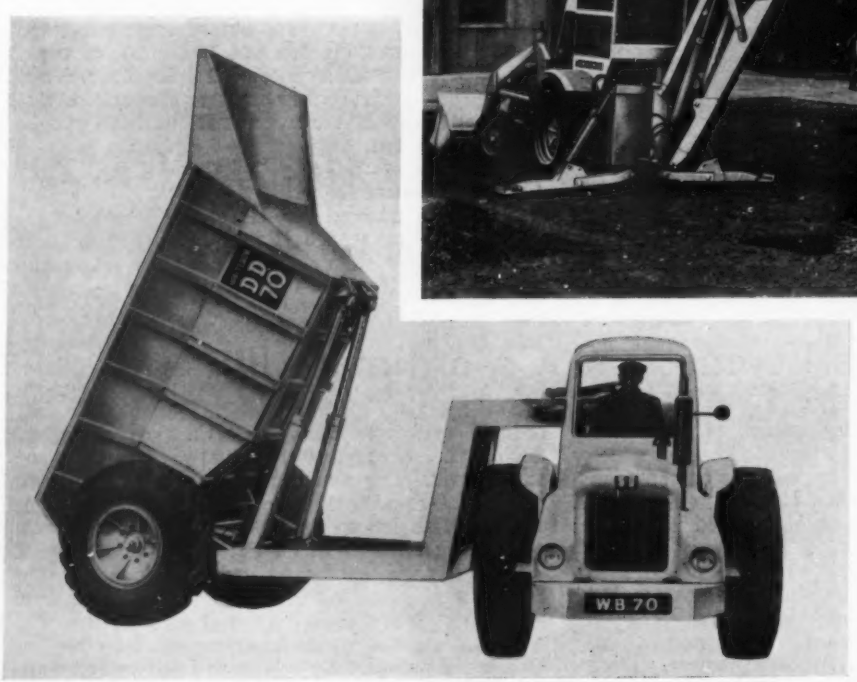


Fig. 1 (below). Ten-ton dumper consisting of four-wheeled machine with two-wheeled tractor

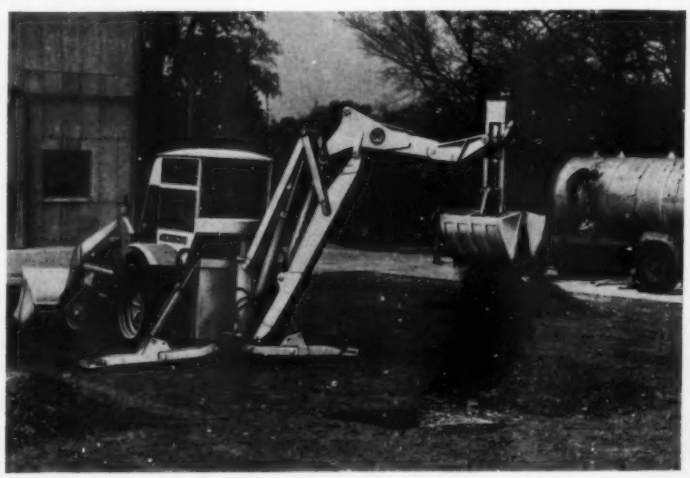


Fig. 2 (above). Dinkum power shovel controlled from a cab

chassis and is provided with hydraulic steering by means of four double-acting rams controlling the movement of the pivot between the tractor and the dumper chassis. A steering lock is thus achieved of 180°, which can be obtained without any forward movement of the vehicle, and at full lock the turning circle has a radius of only 13 ft. This feature renders the dumper extremely manoeuvrable in confined spaces such as tunnel headings. The arrangement also ensures that the tractor wheels, which both drive and steer, are fully loaded. Two double-acting hydraulic rams tip the wagon body to an angle of 65°, which raises the floor of the wagon practically to the vertical. The engine is a four-cylinder diesel unit developing 51·8 b.h.p. at 1,600 r.p.m. Six forward and two reverse speeds are provided, giving a top-gear speed of 13.16 m.p.h. when the engine is running at 1,600 r.p.m. Braking is by mechanical linkage on the front wheels and by servo-vacuum on the rear wheels, in addition to a parking brake. The hydraulic system is served by a vane-type oil pump delivering 13 g.p.m. at 1,600 r.p.m. The flexible hoses are tested to 6,000 lb. per sq. in. The driver's cab gives full all-round vision; it is glazed with Triplex safety glass and, with the bonnet, is made of toughened glass fibre. The capital and operating costs of the Dinkum Dumper 70, as it is designated, are stated to be strongly competitive in comparison with conventional dumpers of similar or larger capacities.

Another machine of special interest is available either as an excavator (Dinkum 60), a power shovel (Dinkum 66) or as a combined machine. The excavator can cut trenches or clear channels up to 13 ft. 6 in. deep (or 17 ft. with an extension), and can be fitted with a hydraulic power grab by means of which rectangular holes can be cut for foundation footings, etc. Many other attachments are available for special purposes. The shovel is normally of $\frac{3}{4}$ cu. yd. capacity, but a $1\frac{1}{8}$ cu. yd. light-material shovel can be supplied, and a bulldozing blade can also be fitted. Fig. 2 shows a combined machine cutting square holes for foundation footings.

An unusual type of equipment was represented by a contract, under execution at the time of our visit, for 12 self-propelled barge-mounted Dinkum Diggers for British Waterways for dredging canals. The excavator unit is mounted in the bow of the vessel and is fitted with a hydraulic power grab. The machine is controlled from a cab towards the bow, a cabin for the crew is placed amidships, and aft is a raised pilot's deck. A 30 h.p. Lister diesel engine provides power both for the hydraulics and for the propeller.

Examples of smaller shovels and excavators were also shown, and it was announced that Whitlock Bros. Ltd., had completed an agreement with Ransomes Sims & Jefferies Limited, Ipswich, to take over the manufacture and marketing of the entire range of earthmoving equipment for the Ransome MG industrial crawler tractor.

A Hamilton Falls Development

In an Editorial Note in our May 1960 issue we gave a fairly full outline of the Twin Falls development now being undertaken by Hamilton Falls Power Corporation Limited on the Unknown River, Labrador, a tributary of the Hamilton River. An initial installation of 120,000 h.p. is planned, to commence generation in June 1962, to serve the Iron Ore Company of Canada and the Wabush Iron Company. This capacity will be available on a run-of-river basis, but subsequent storage works could raise the firm capacity to 300,000 h.p. We are now able to publish the accompanying photographs of the terrain. Fig. 1 is a view of Scott Falls, one of the two sets of falls offering an aggregate fall of about 400 ft., of which Scott Falls provides 90 ft. Running roughly parallel with the Unknown River is a dry gorge which is to be used as the tailrace. It is some 300 ft. below the level of the river upstream of the falls. This gorge is depicted in Fig. 2.

The Roselend Dam will control the waters flowing into the Roselend valley from the Beaufort massif. Other streams will also be diverted into the catchment area by means of some 60 km of collector tunnels (with diameters of between five and nine metres). A second dam at Chapelle de St. Guerin will control the waters of the Poncellamont Gorge. Illustrated above is an artists impression of the Roselend Dam.

FRANCE PUTS THE SAVOY ALPS TO WORK

Atlas Copco and Sandvik Coromant equipment used extensively at Roselend

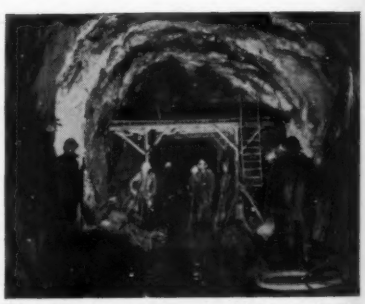
TO THE TOURIST, the Savoy Alps may conjure up visions of winter sports or long, lazy summer holidays, but to Electricité de France the region means power! The French State power board is building a series of storage reservoirs in the upper Isere area of the Alps, not far from the Italian border. The most important part of the scheme is the Roselend Valley section which will increase France's power reserves by 1,000 million kWh a year. This project involves building two dams and a 476,000kW power station at Bathie which will be the most powerful in France.

Atlas Copco compressed air equipment is being used almost everywhere on this project. For drilling the main tunnels more than a hundred BBD41WK rock drills with pusher feeds and several thousand Sandvik Coromant drill steels are being used by the main contractors, Borie, Ets. Seinrapt & Brice, Gebro, Pegas & Pugeat, Stribick Et Fils.

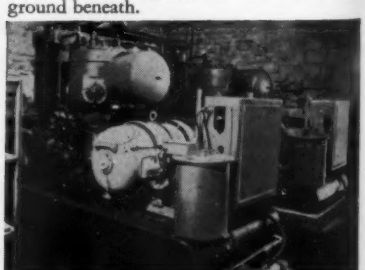
Sales and Service in ninety countries

Atlas Copco is the world's largest organisation specialising solely in compressed air equipment. Products include stationary and portable compressors, rock drills, loaders and air tools and equipment of every description. Wherever you are, the international Atlas Copco group will supply expert advice on the selection of equipment and provide a complete after-sales service.

General view of work on the Roselend Dam.



The Headrace Tunnel will be 13 km in length and 4.2 metres in diameter. Single deck platforms are used for drilling, with four men working on the platform and four on the ground beneath.



Two Atlas Copco AR3L compressors supply the air power at the Versoyen drilling site.

Atlas Copco puts compressed air to work for the world

ATLAS COPCO AB, STOCKHOLM 1, SWEDEN

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Abstracts from the World Technical Press

Concrete-Dam Design Work

This article is a translation of a report presented to the International Conference held in Madrid in June 1959 on Structural Models, and deals with the special problems arising in the study of concrete dams by means of model tests. The advantages of this experimental method as compared with analytical procedures are discussed. It is shown that the latter are unable to determine the state of stress in such structures, especially in the case of complex patterns or in the presence of unusual features such as cracks, open joints, openings in the dam body for spillways, penstocks or outlets, zones of exceptional rigidity in the dam, artificial abutments, or instances of exceptionally heavy or special stresses. The general usefulness and versatility of model studies are demonstrated by typical instances of stress determination under the special conditions mentioned above on a series of dam models tested at the Laboratório Nacional de Engenharia Civil. (Manuel Rocha, J. Laginha Serafim and M. Cruz Azevedo, *Electricidade*, No. 13, January–March 1960, p. 3, 16 pp., 26 ff.)

Applying the Techniques of Finite Differences to Dam Studies

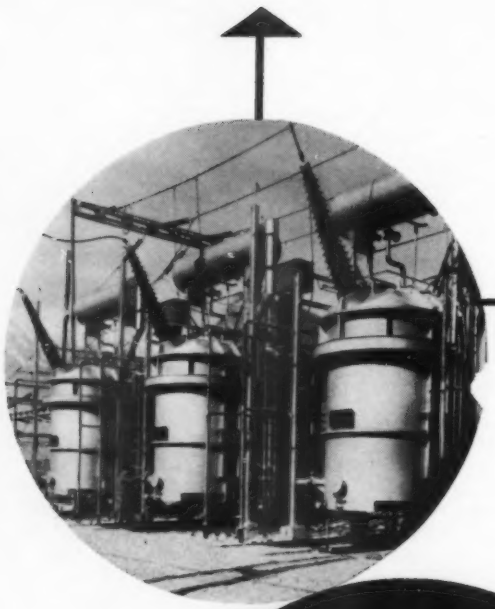
This article, based on a paper read by the author at the Laboratório Nacional de Engenharia Civil in June 1959, reviews the application of the techniques of finite differences to the solving of problems connected with the study of stresses in gravity and shell-type dams. The techniques described and discussed deal with problems such as distribution of temperatures in plane areas, calculating stresses and displacements in gravity dams, analysing cylindrical shells in function of the displacements, as well as three-dimensional elasticity problems. Graphs are appended for each case instanced. Special reference is made to the relaxation method for solving systems of equations which govern dimensional problems of elasticity as well as between media differing in elastic characteristics, and techniques are suggested for investigating the influence of foundation characteristics on the state of stress in a gravity dam. (O. C. Zienkiewicz, Northwestern University, U.S.A., *Electricidade*, No. 14, April–June 1960, p. 155, 15 pp., 26 ff.)

New Queensland Hydro Scheme Extension

Tenders have been invited for civil-engineering works for the Barron River hydro-electric extension project, which will be adjacent to the Barron Falls power station near Kuranda. The installations will be completely independent of the original works, except that the new pondage weir will be built on the same site as the existing weir and its crest will be raised from the present maximum height of about 12 ft. above the river bed to nearly 25 ft. A reinforced intake structure forming the right abutment of the weir will lead water from the pondage into a 5,390 ft. tunnel, known as the "Horizontal Tunnel", which will be excavated almost entirely in sound rock, at a depth below surface varying from 50 to 425 ft. Near the downstream end of the Horizontal Tunnel there will be a concrete-lined surge tank of simple cylindrical type, 24 ft. diameter and about 135 ft. deep, and the remaining 100 ft. length of the tunnel downstream from the surge tank will be steel lined. A small chamber housing an 8 ft. 9 in. diameter butterfly valve and vertical steel bend will be inserted between the horizontal tunnel and the inclined pressure tunnel. At a point about 115 ft. before the power station, the pressure tunnel extends horizontally with a bifurcation to the two turbines. The actual length of the pressure tunnel will depend on the location adopted for the power-station cavern, but the maximum length between upper and lower bends is not expected to exceed 1,350 ft. The power station, approximately 138 ft. long, 32 ft. wide and 65 ft. high, will be excavated in solid rock, lined with concrete, and have a reinforced concrete cylindrical vaulted roof. Normal access will be through a concrete-lined sloping tunnel about 360 ft. long, and a second tunnel, about 400 ft. long, leaving the machine hall near roof level, will serve as ventilation, cable gallery and emergency exit. The generating equipment will consist of two 30,000 kW vertical-shaft sets, driven by 40,000 h.p. Francis turbines. The elbow-type draft tubes from the two turbines join in an excavation 18 ft. diameter and 100 ft. high which will serve as a gate chamber and tailrace surge tank. A 12 ft. wide tailrace tunnel of the fully drowned type leads about 900 ft. from the surge tank to an open channel discharging into the river. The lower working bench and switchyard will be formed partly by excavation into the side of the gorge and partly by filling behind a reinforced-concrete retaining wall built on the right-hand side of the riverbed, using spoil from the power station and tunnel excavations. An exploratory tunnel on the line of the permanent cable and ventilation tunnel is now being driven into the area in which the machine room will be excavated. A portion of the tailrace tunnel and a reinforced-concrete retaining wall on the river side of the working trench will be constructed prior to commencement of the contract together with a culvert to divert the adjacent gully. (*Australian Civil Engineering*, Vol. 1, No. 9, June 3, 1960, pp. 40-42, 1 f.).

Silver Falls Project

This paper, presented at the Annual General Meeting of the Engineering Institute of Canada, Winnipeg, May 1960, describes the Silver Falls generating station which was built in response to the continuous demand for more electrical power in North-western Ontario. The power site is located aproximately 30 miles north-west of Port Arthur on Kaministikwia River, and is readily accessible by road and rail. The station has an installed capacity of 45 MW, designed for both base and peak loading, and for remote-control operation. The essential features consist of an intake structure, a 300 ft. intake shaft, a 2 mile long tunnel, a surge shaft and surge tank, and a single-unit power-station. Hydraulic power is derived from the 350 ft. head between Dog Lake and Little Dog Lake on the Kaministikwia River. Dog Lake constitutes the storage reservoir for Silver Falls and is also the headwater of Kaministikwia River which falls some 775 ft. in its 50 mile course to Lake Superior.



Power Stations and Substations

Sécheron

Sécheron Works Co Ltd, Geneva, the specialists in the electrotechnical field, supply all kinds of equipment for complete power stations and substations:

High capacity A.C. and D.C. motors and generators. Power transformers of all sizes and voltages. Automatic regulators for various types of controls. Pumpless mercury arc rectifiers, semi-conductor rectifiers.

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Part of this head, 194 ft., has been utilised since 1906 by the old Kakabeka Falls plant. (R. A. Forrester, *The Engineering Journal*, Vol. 43, No. 4, April 1960, p. 83, 8 pp., 4 ff.).

Rio Sao Francisco Development

This article deals especially with the harnessing of the Paulo Afonso waterfalls, south of Petrolandia, which are one of the most conspicuous features of this Brazilian development. Work on the initial stage of construction started in 1950 and was completed in 1954. Following the opening up of new oilfields near Salvador, and subsequently at Alajoas, a second-stage extension is now in progress. From the scanty information available, it appears that this extension is restricted to the addition of a third 83,000 h.p. generating set to the underground machine hall. It is hoped this power increase will greatly contribute to the further industrial development of the north-east region of the country. Aluminio do Brazil are to begin this year the construction of a plant with an initial annual output of 4,000 tons, planned to rise to 20,000 tons by 1964. The Rio Sao Francisco, 2,900 km. in length, drains an area of 688,000 sq. km., and is navigable practically on its whole course, with the exception of a 38 km. stretch of its headwaters and of the 150 km. long cascade of rapids near Petrolandia. These rapids present an aggregate gross head of 200 m., to which the Paulo Afonso drop alone contributes 90 m. There, the flow of the river, totalling 21,000 cu. m. per sec., splits into many smaller falls which make it exceedingly difficult to concentrate a large volume of power water at a single point. In fact, the high net head available alone secures the profitability of the project, and, even with the help of the great pool available, hardly more than 1% of the discharge is now harnessed to generation. This pool was created by building above the power fall two retaining walls, each several kilometres in length, varying in height from 4 to 5 m., and 2·5 m. in thickness, which converge towards the fall to form a gradually narrowing reservoir. With the support of a system of locks and spillweirs, a permanent supply of 270 cu. m. per sec. goes to the turbines which at 81 m. head produces 900,000 kW. The incoming water reaches the intake through three 104·62 m. tunnels, 4·8 m. diameter at the inlet, each of which discharges 90 cu. m. per sec. There is a single tailrace tunnel, 180·35 m. long, 10·00 m. wide, designed for a maximum discharge of 270 cu. m. per sec. The two first-stage turbines (General Electric), each with an output of 83,000 h.p at 200 r.p.m., are housed in a cavern measuring 60·15 by 15·00 m. in plan and 31·34 m. in maximum height. Each turbine drives a 60,000 kW generator; the current, 13,800 V at 60 c.p.s., passes first through to banks of three single-phase 67,500 kVA transformers, and then reaches the transmission line at 13·8/220 kV. (Dr. Helmut Gravert, *Die Wasserwirtschaft*, Vol. 50, No. 7, July 1960, p. 185, 4 pp., 8 ff.).

First Hydro Project in Labrador

Within two years Labrador is to have its first hydro-electric power plant at Twin Falls on the Unknown River, a tributary of the Hamilton River. Initial capacity is to be 89,500 kW. The topography at Twin Falls is very favourable to water-power production. In a three-mile stretch of river, there are two sets of falls, each set in turn being made up of twin falls, and there is a total drop on this distance of 400 ft. Running roughly parallel with the river is a dry gorge the bed of which, at its upper end, is about 300 ft. below the river level above the falls. The plan of development is to divert the river from the plateau level through a canal and penstocks to a power house in this gorge. Without regulation the 8,400 sq. m. catchment will provide an estimated minimum flow of 3,450 cusecs capable of producing, at the net head of 290 ft., 89,500 h.p. firm at 80% load factor. For the initial installations, the plant will therefore be run-of-river. As demand increases, up to 12 ft. of storage can be provided in two large lakes from which the Unknown River flows. Regulated flow in a dry year will then be 8,100 cusecs, sufficient for 225,000 kW firm at 80% load factor. (*Engineering News-Record*, Vol. 164, No. 26, June 30, 1960, p. 43.).

Iron Gate Projects

The 120 km. stretch of rapids from Orsova to Turnu Severin marks the sharp transition between the middle stretch of the Danube in the Pannonian depression and the flat lower course of the river in the Wallachian plain. This transition, caused by a rocky sill between the spurs of the Carpathians and of the Balkans, presents a head of almost 30 m. and reduces the width of the river from its normal 600 to 700 m. to a mere 150 m. The gradient of the river which, when leaving Austrian territory had sunk to 0·006% rises again to 0·05%, even reaching 0·02% at some points, and the average velocity of the flow, 4·5 m. per sec., is five times as high as in the neighbouring sections, i.e. 50% higher than at the downstream end of the Austrian stretch. The obstruction to navigation at the Iron Gate is best illustrated by the fact that the usual 10 to 20 barges sailing in a string from Galatz upstream, have to be towed one by one to negotiate the rapids, thus lowering the payload of the powerful Danube tugs from seven tons to half a ton per horsepower. The urgency of an extensive correction of this awkward stretch of the Danube had not escaped the attention of the old Hapsburg Monarchy, since it would have solved the navigation problem and opened the way to power generation on a grand scale; in fact, an old Austrian project contemplated a two-step canalised section with two power pools at Sip and Juc with an installed capacity of 365 MW and a yearly production of 2·5 to 3 TWh. Yugoslavia and Rumania have succeeded Austria and Hungary as the interested parties, and their co-operation in the Iron Gate project goes as far back as the end of World War I. In the various two-step and three-step developments worked out in the two countries between 1920 and 1943, and the German project initiated during World War II, the installed capacity of the scheme rose to 690 and 870 MW and production to 6 and 7 TWh. These figures were far in excess of the two countries' requirements at the time, but intensive industrialisation has brought about an enormous demand for power, and studies for the Iron Gate project are now proceeding with the utmost energy. As a basis for the negotiations between the two countries, the Rumanian Research Board for Energetics has investigated a preliminary project in three main and eleven secondary variants, the former applying to the number of power stations (one to three), the latter to pool levels. The three-step scheme, with 15 generating units at Sip and 17 each

at Juc and Islaz is the least economical of the three main variants, since at Islaz the width available does not exceed 625 m., and the necessary installations could only be built in conjunction with a submerged power block fitted with 7 m. high flap gates: Yugoslav counterproposals are more realistic: at Sip, a pool level at E1·65, providing for a head of 24 m. and an installed discharge of 8,340 cu. m. per sec., would produce a capacity of 1,650 MW and a production of 9·2 TWh. The backwater of this scheme would extend 140 km. upstream. A second step in the Yugoslav-Rumanian stretch near Grouya is also under consideration by the mixed commission and would provide, at a head of 6 m., for a capacity of 320 MW and a production of 2,120 GWh; the proposed construction site, however, is 90 km downstream from Sip and has hardly anything to do with the Iron Gate project proper. The incorporation of the Iron Gate scheme into the economy of the two countries is considered as presenting no great technical difficulties. Completion is not expected before 1970, at which time the aggregate home demand is assessed at 35 TWh. The Danube alone would cover 25 to 33·3% of these requirements. (Dr. techn. Rudolf Pard, *Oesterreichische Zeitschrift für Elektrizitäts wirtschaft*, Vol. 13, No. 3, March 1960, p. 79, 5 pp., 8 ff.)

Arnon-Diablerets Scheme

This Vaud Canton scheme, in no way conspicuous by its size, presents in its civil-engineering works, as described in detail in this article, some very interesting features; its back bone is the Arnon Lake, 1,000 m. long from south to north, 400 m. wide, which has had its capacity increased to 7 million cu. m. at its northern end by an earthfill dam equipped with a flood-discharge system. The dam has the following characteristics: 140 m. crest length by 73 m. in width at the base, and 17 m. in maximum height; volume 40,000 cu.m.; thickness of filter 0·80 m.; area of stone-pitched facing 3,700 sq. m. The fill layers are 0·80 m. thick before, and 0·60 m. after compacting. Extensive tests on a 400 sq. m. smooth floor were effected on site before actual compacting began; their results are reviewed in detail. The flood-discharge system consists of a rectangular-shaft spillway constructed near the left bank of the lake and connecting with a tunnel through the foot of the dam, the tunnel discharging into a stilling pool. There are two intakes, one built during the first construction stage about halfway between the northern and southern tips of the lake; the subsequent raising of the lake level had already been taken into account, so that this intake structure required no alteration. The second intake, at Ayerne, collects the waters of the Isenau catchment through the Ayerne torrent and conveys them to the lake by an intermediate gallery and the main tunnel. Avalanches being rather frequent in the Ayerne Valley, this intake is protected at the top by a strong ferroconcrete roof, and upstream as well as laterally, by embankments reaching the level of the roof. The supply system consists first of the old Arnon tunnel, 4·5 km. long, plugged at its downstream end and connecting slightly upstream of the plug with the 960 m. Crettaz tunnel, which, in its turn, leads to the 1,200 m. penstock, 80 cm. in diameter, decreasing upstream to 70 cm. Part of the upstream section of the penstock is laid in a tunnel, and from the Coutaz massif to the power house is buried in a trench. In addition to strong anchorages at either end, this buried section of the penstock, which runs in a straight line in the horizontal plane but follows closely the profile of the ground, is divided into three subsections by means of intermediate anchorages which are fitted with adjusting sleeves acting as expansion joints. These sleeves alleviate the effect on the penstock of longitudinal stresses arising through temperature changes when the conduit is put into operation, check the sliding of the penstock downwards, and also ensure protection against landslides. This device was conceived as a result of the experience gained at the Vouvry plant with regard to the necessity of periodically relieving stresses in penstocks, particularly in very steep sections. The Diablerets powerstation houses a single two-nozzle 5,000 kW Pelton turbine, designed for a gross head of 378·15 m. The tailrace is a buried ferroconcrete conduit 80/70 cm. in diameter and 190 m. long. The Ayerne intake, completed in October 1950, began to contribute to the impounding of the Arlon Lake in the spring of 1957, the Diablerets powerstation being put into service at the beginning of September of the same year. (R. Pernet and R. Dumont, Ing. EPUL., *Bulletin Technique de la Suisse Romande*. Vol. 86; No. 2, January 16, 1960, 15 pp.; No. 3, January 30, 1960, 6 pp.; 20 ff.)

Hydraulic Model Studies

The studies reviewed in this paper were devoted especially to the design of overflow spillway crests and high-head sluices on dams, the two types of structure being dealt with in separate chapters. The design criteria for the two types of structure have been standardised to a considerable extent, and can be followed to give safe designs in ordinary cases. In instances of important works proposed for flood disposal under more drastic conditions it is always advisable, however, to test the designs by means of hydraulic models. These experiments prove that the time and money spent are more than repaid by the higher degree of efficiency, reliability and economy achieved in structures designed in accordance with their results. (D. V. Joglekar, *Irrigation and Power*, Vol. 17, No. 1, January 1960, p. 22, 19 pp., 12 ff.)

NOTE. Other articles of interest included in the above issue: "Theory of High Coefficient Weirs, by B. M. Bharadwaj, p. 40, 8 pp., 5 ff.; "A suggested Method to estimate Flow in Open Circular Channels," by K. R. Pattabhiramiah and N. S. Lakschmana Rao, p. 56, 5 ff.

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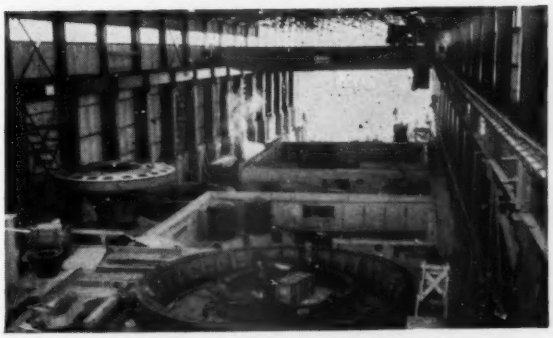
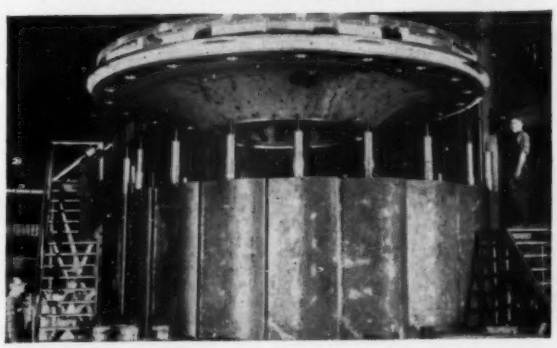
Kelsey Power House during construction.*



Power House Interior during construction.*

Runner, Hub and Head Cover prior to installation.*



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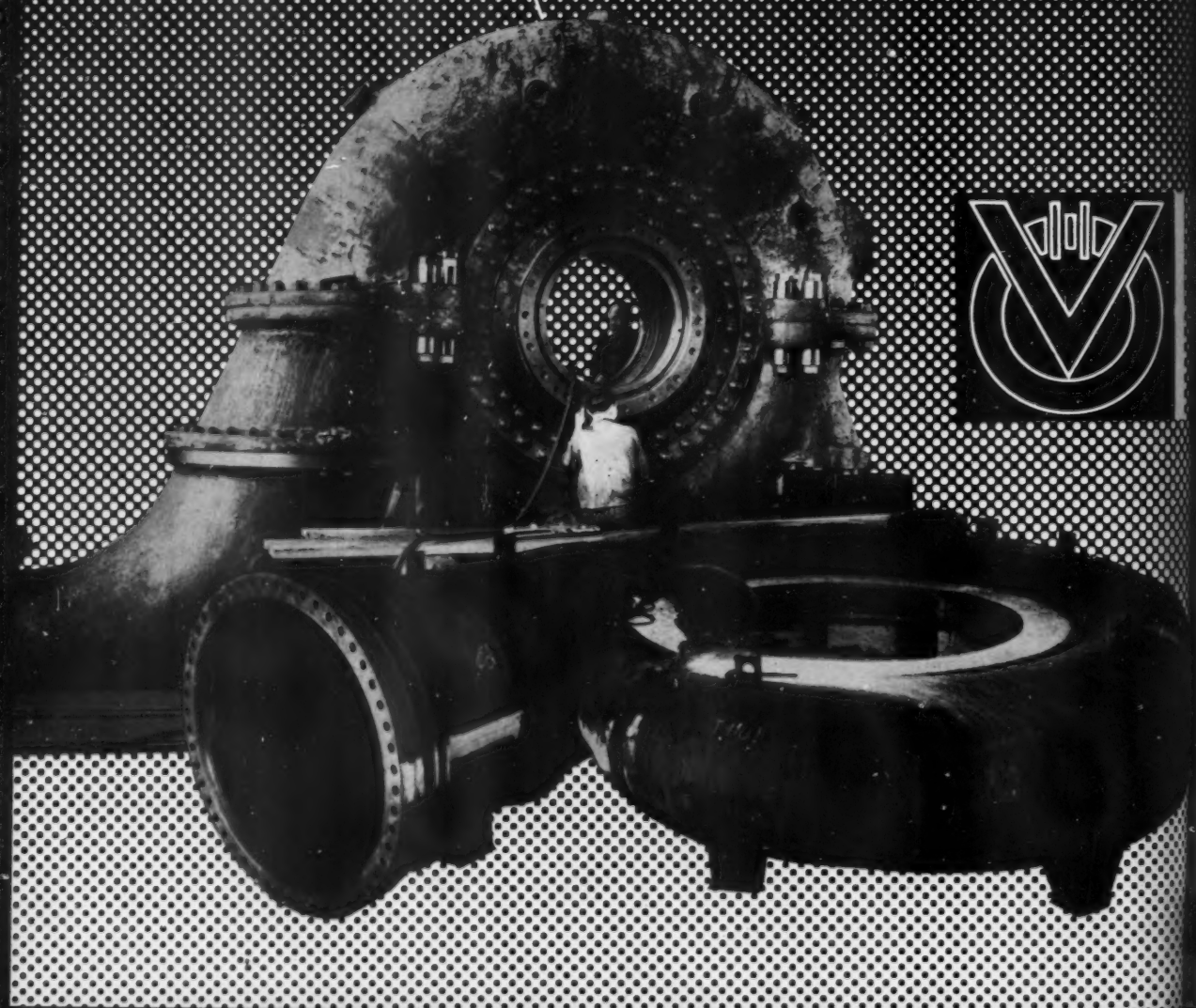

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Government of Ghana–Volta River Project

Invitation for tenders — Contract No. A. 3 Akosombo Development: Construction of Dams, Power Plant and Appurtenances

DESCRIPTION OF PROJECT

The Initial Development of the Volta River Project at Akosombo will include a rockfill dam with a maximum height of about 370 feet and volume of about 10,900,000 cubic yards, a rockfill saddle dam with a maximum height of about 120 feet and a volume of about 750,000 cubic yards; an intake structure and six 24-foot diameter penstocks; a 213 ft. rated head power plant with an installed capacity of four Francis turbine-driven 128 mega watt generating units with provision for the future addition of two similar units; a spillway 12–42 × 42 ft. tainter gates; a 25-foot diameter diversion tunnel approximately 1,000 feet long; and other appurtenances.

PROPOSED CONTRACT

Work under Contract No. A-3 will include the construction of the above-mentioned structures, as well as the installation of generating plant and other major equipment furnished by the owner.

SITE INFORMATION

The proposed development is to be located at Akosombo about 60 miles north-east of the capital city of Accra. The job site is accessible by first-class all-weather roads from both Accra and the harbour of Tema, where heavy lift facilities for unloading and handling of equipment may be installed by the Contractor. Foundation investigations and preparatory construction of housing, warehousing and other facilities are presently under way. The main dam and other appurtenant structures, including the spillway, saddle dam and intake are to be ready to begin storage of water by July 1964, and the first generating unit is to be ready for commercial operation by September 1965.

BIDDING PROCEDURE

Interested firms which have satisfactorily completed comparable projects should apply to the Consulting Engineers for the Government of Ghana:—

Kaiser Engineers and Constructors, Inc. (Volta Project),
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or,

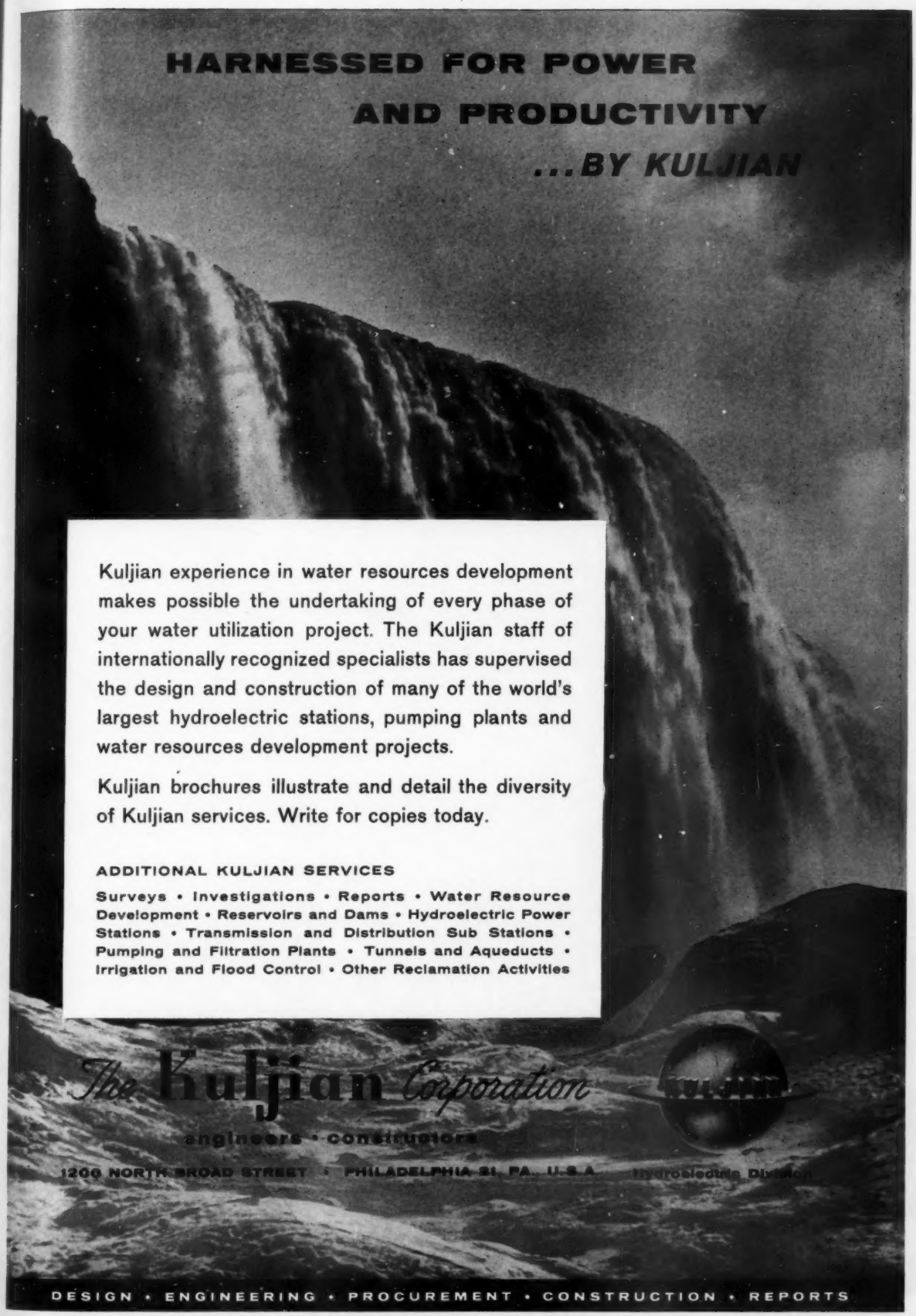
Kaiser Engineers and Constructors, Inc. (Volta Project),
Kaiser Center,
300 Lake Side Drive,
Oakland 12,
California,

for copies of the contract documents; two sets of documents may be obtained by making a non-refundable payment of U.S. $50 or £G17 17s. 6d. Additional sets may be obtained at U.S. $25 or £G8 18s. 9d. each.

Prequalification forms will be enclosed with the documents. Bids will be received only from those contractors who, having submitted the full information required for prequalification, are subsequently selected by the Government. The determination of the Government shall be final. Bids for Contract No. A-3 will be invited on a fixed unit price basis as set forth in the Contract Documents. It is anticipated that bids will be opened on about 17th January, 1961, and the award of the Contract will be made in about April, 1961. Preliminary security of £G250,000 will be required with tenders.

Prequalification forms may also be obtained directly from the Consulting Engineers at Oakland, California. Completed prequalification forms must be submitted by interested tenderers to the Consulting Engineers at Oakland, California, not later than 12th October, 1960. Tenderers will be invited on 1st–3rd November to visit the proposed site and view foundation exploration, including shafts, trenches and cores from bore holes. This visit will include examination of Tema Harbour facilities and the Akosombo access road. Prospective tenderers should notify the Consulting Engineers before 20th October the names of persons desiring to attend so that hotel reservations and other arrangements may be completed. Prospective visitors should obtain passport, visas and Yellow Fever immunisation at least two weeks in advance.

A prebid meeting is planned at the office of the Consulting Engineers in Zurich, Switzerland, on 6th December, at which time additional information on foundation exploration will be made available to answer questions by tenderers. A written addendum will be issued to all tenderers following this meeting.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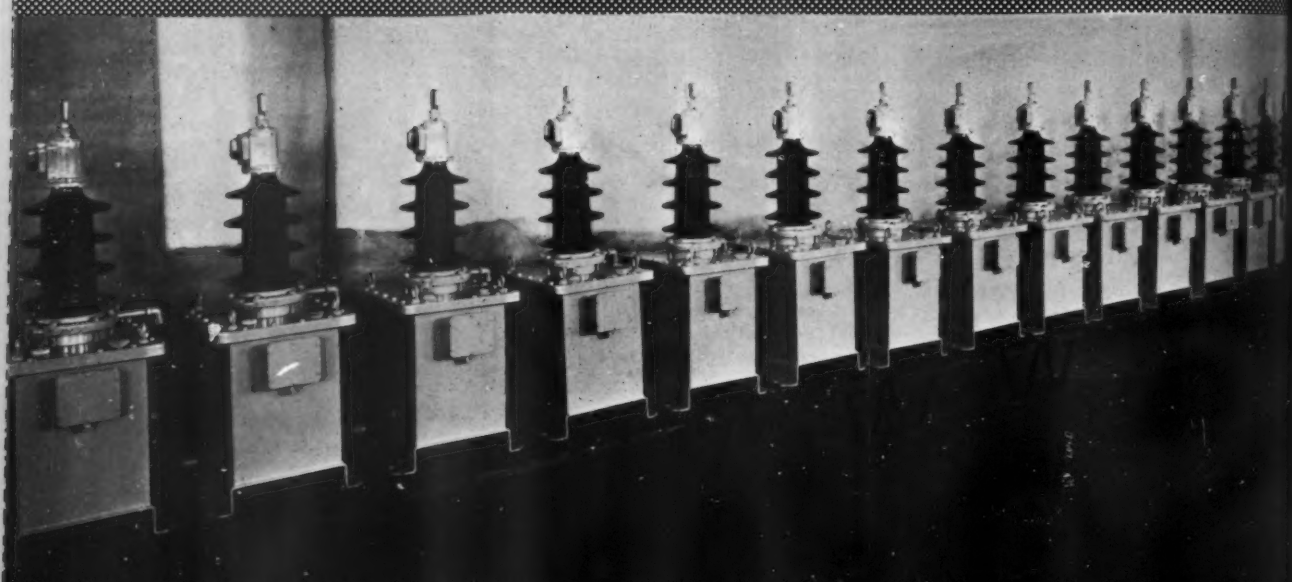

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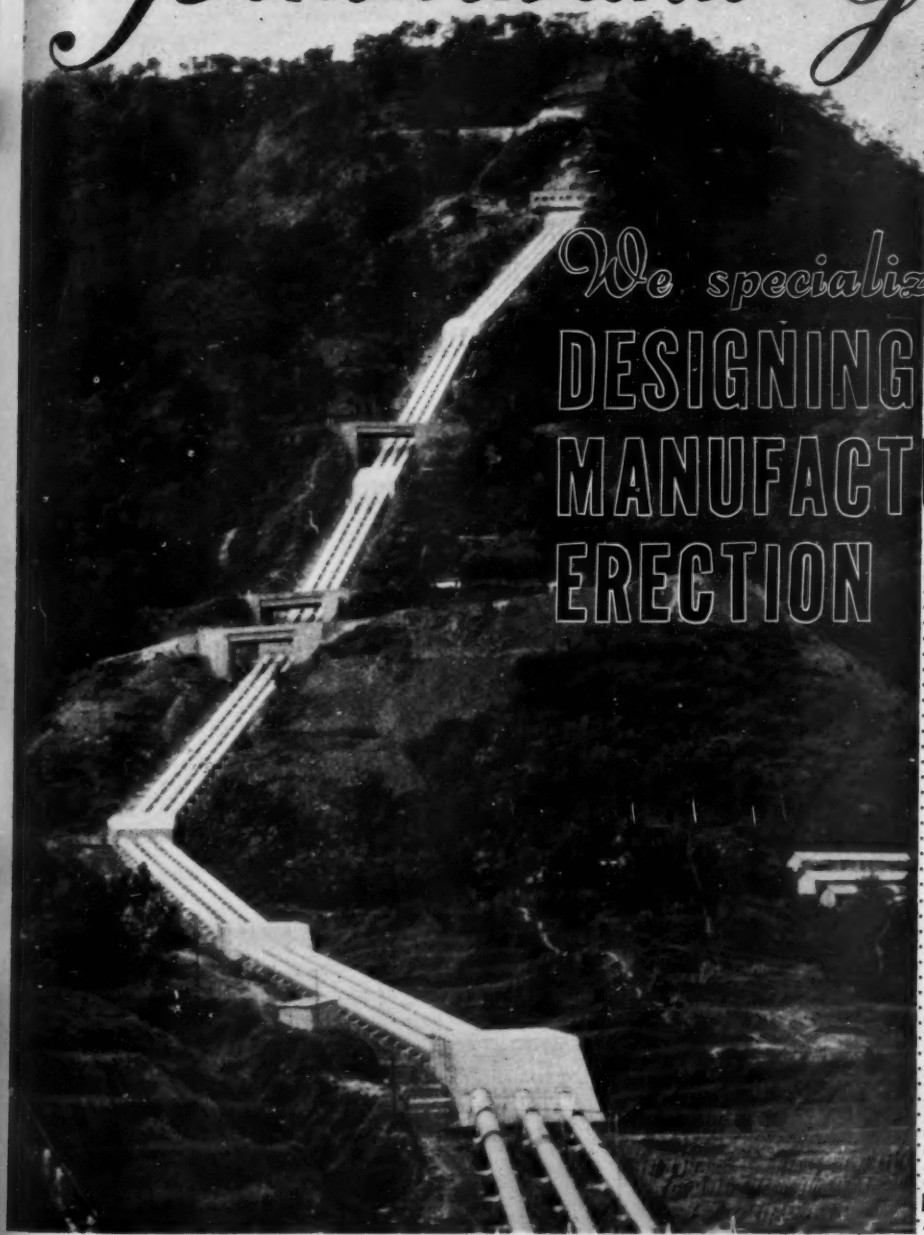

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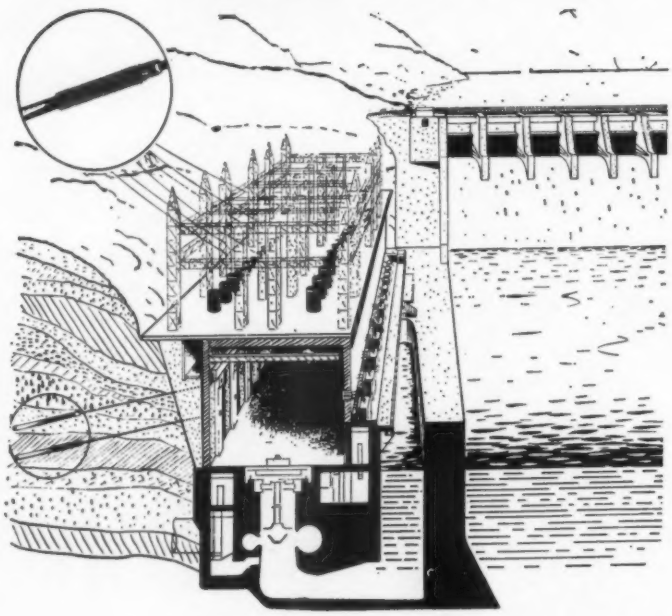

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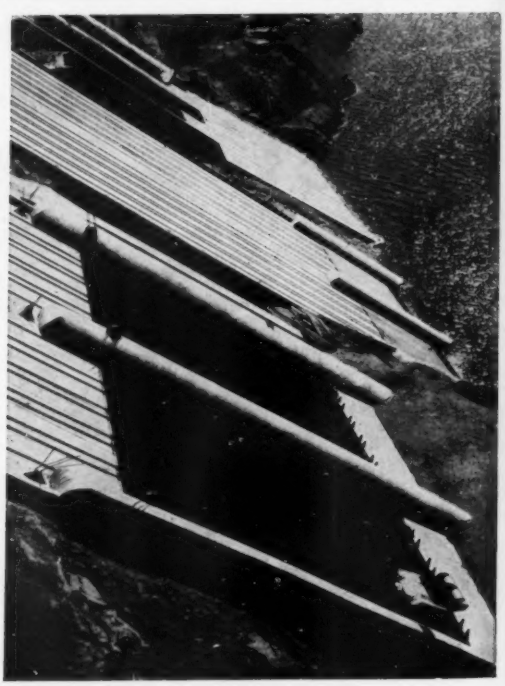

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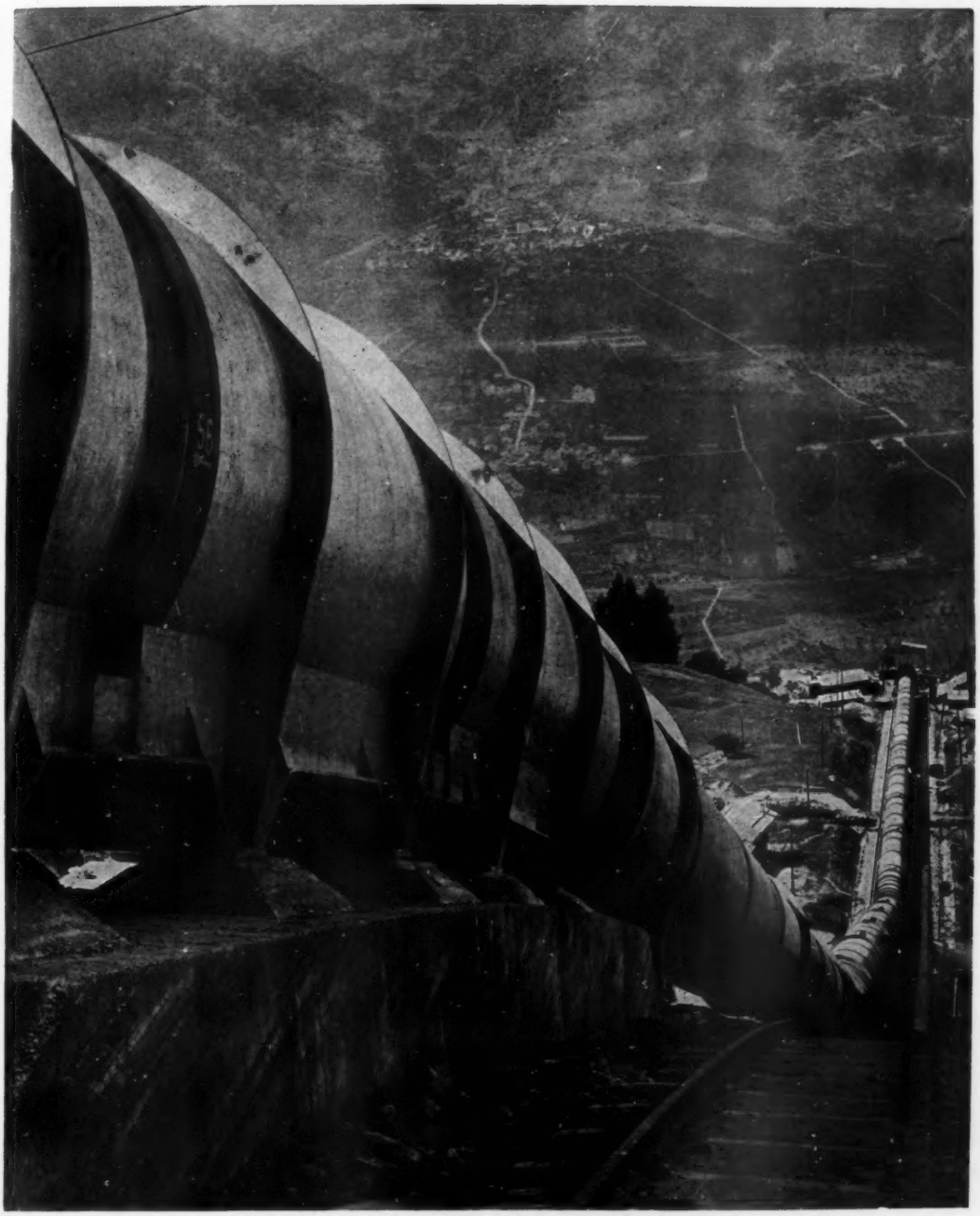

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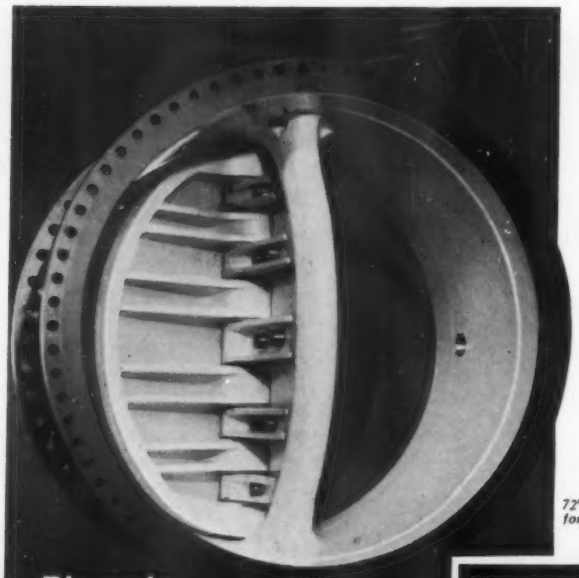

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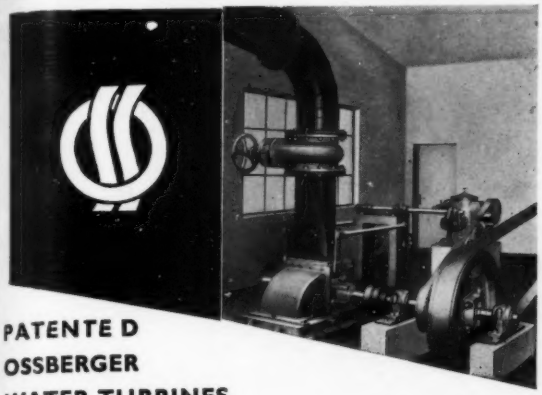

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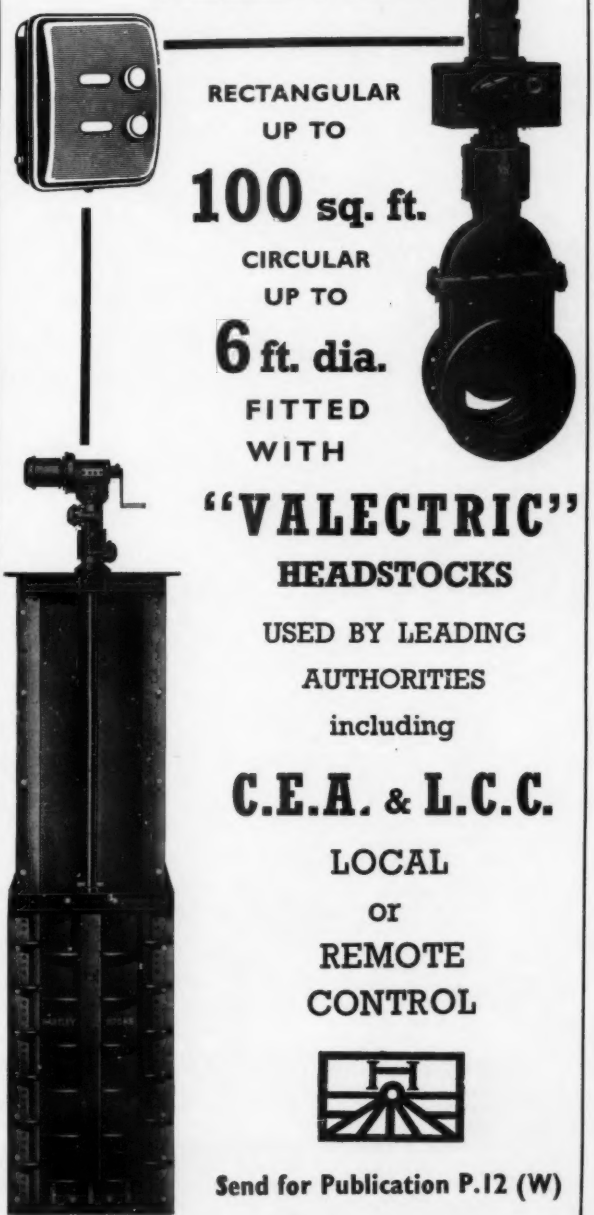

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INDEX TO ADVERTISEMENTS

A

Acciaieria E Tubificio Di Brescia ... ... —
Allgemeine Elektricitäts-Gesellschaft 45
Alimark Verken ... ... —
Allis-Chalmers Hydraulic Division ... ... 19 & 31
Allmanna Svenska Electriska Aktiebolaget ... ... —
Aluminium Wire & Cable Co. Ltd. ... ... —
Anderson, Grice, The Company, Ltd. ... ... —
Ansalda San Giorgio, S.p.A. 48
Ardelt Industries of Canada Ltd. ... ... —
Armfield Hydraulic Engineering Co. Ltd. ... ... —
Associated Electrical Industries (Manchester) Ltd. —
Associated Electrical Industries (Rugby) Ltd. Front Cover
Associated Electrical Industries (Woolwich) Ltd. ... —
Ateliers de Constructions Electriques de Della ... 42
Atlas Copco, A.B. ... ... 26, 27 & 55

B

Balfour, Beatty & Co. Ltd. ... ... —
Bell, Theodore & Co. Ltd. ... ... —
Birkett, T. M., Billington & Newton Ltd. ... ... —
Bochumer Verein ... ... Inside Back Cover
Bouchayer & Viallet ... ... —
Boving & Co. Ltd. 5
Boyles Bros. Drilling Co. Ltd. ... ... —
British Ropeway Engineering Co. Ltd. ... ... —
Brown, Boveri & Co. Ltd. 33
Bruce, Peebles & Co. Ltd. 50
Bucyrus-Erie Co. Ltd. 30
Buss, A.G. 28
Butters Bros. & Co. Ltd. 35

C

Canadian General Electric Co. Ltd. ... ... —
Canadian Vickers Ltd. 37
Canadian Wood Pipe & Tanks Ltd. 40
Cementation Co. Ltd. ... ... —
Ceretti & Tanfani Ropeway Co. Ltd. ... ... —
Charmilles Engineering Works Ltd. 44
Cockburns Ltd. 36
Compagnie Industrielle de Travaux ... ... —
Consolidated Pneumatic Tool Co. Ltd. 54

D

De Havilland Propellers Ltd. ... ... —
de Roll, Louis, Ironworks Ltd. 3
Dominion Engineering Co. Ltd. 57
Doulton Industrial Porcelains Ltd. 24
Drees & Co., G.m.b.H. ... ... —
Dresser Manufacturing Division ... ... —

E

Elliott Bros. (London) Ltd. ... ... —
English Electric Co. Ltd. ... ... Outside Back Cover
English Steel Forge & Engineering Corporation Ltd.
Escher Wyss Ltd. 25

F

Ferranti Ltd. 11
Ferrum Montage 16
Fischer, Ltd., George ... ... —

G

Galileo Officine di Battaglia Terme ... ... —
General Electric Co. Ltd. 12
Ghana, Government of 60
Gilbert Gilkes & Gordon Ltd. 46
Giovanola Freres, S.A. 61
Glenfield & Kennedy Ltd. 20
J. Gordon Valves Ltd. 62

H

Harland Engineering Co Ltd., The 52
Hartley's (Stoke-on-Trent) Ltd. 63
Henderson, John M. & Co. Ltd. 38
Hitachi Ltd. 34
Holland & Hannen and Cubitts Ltd ... ... —
Huhn, G. ... ... —
Hydraulics & Pneumatics Ltd. ... ... —
Hydraulic Service & Equipment 62

I

Impresit Kariba (Pvt) Ltd. ... ... —
International Engineering Co., Inc ... ... —
International General Electric Co. ... ... —

J

Jonneret, S.A. Ateliers de Construction 64
Joy-Sullivan Ltd. ... ... —

K

Kaiser Engineers and Constructors Inc. 60
Karlstads Mekaniska Werkstad, Akt. 6
Krupp, Fried. Maschinen- und Stahlbau ... ... —
Kuljian Corporation, The 61
Kvaerner Brug ... ... —

L

Leffel, James & Company, The 10
Lepper Transformatorenwerk August ... ... —
Le Materiel Electrique, S-W ... ... —

M

Magrini, S.p.A. 39
Mannesmann-Export, G.m.b.H. ... ... —
Marelli, Ercole & Co., S.p.A. ... ... —
Maschinenfabrik Augsburg-Nurnberg, A.G. 13
Maschinenfabrik Edward Ruch ... ... —
Maschinenfabrik B. Maier ... ... —
Micanite & Insulators Co. Ltd., The ... ... —
Michell Bearings Ltd. 66
Mitchell Construction Co., The 29
Mitsubishi Electric Manufacturing Co. 14

N

Newport News Shipbuilding & Dry Dock Co. ... —
Neyrpic 21
Nippon Gaishi Kaisha Ltd. 32
Nuttall, E., Son & Co. (London) Ltd. 22
Nydqvist & Holm, A/B ... ... —

O

Oerlikon Engineering Company ... ... —
Ossberger Turbinenfabrik 67

P

Phoenix-Rheinrohr, A.G. ... ... —
Pirelli-General Cable Works Ltd. 41

R

Reyrolle, A. & Co. Ltd. ... ... Inside Front Cover
Ransomes & Rapier Ltd. 15
Rheinstahl Union Brückenbau-Akt. Ges. ... ... —
Rip Bits Ltd. ... ... —
Riva Costruzioni Meccaniche ... ... —
Rosenthal Isolatoren, G.m.b.H. 67
Ruston Bucyrus Ltd. ... ... —

S

S. A. Ateliers De Secheron 56
SACE Costruzioni Elettromeccaniche ... ... —
Sakai Iron Works Co. Ltd. 63
Salvi, A. & Co. 47
Salzgitter Maschinen Aktiengesellschaft 7
Savoisienne 43
Scarpa & Magnano 62
Siemens-Schuckertwerke, A.G. ... ... —
Smith, Fredk. & Co. ... ... —
Smith, S. Morgan Company ... ... —
Soc. p. Az. Cementi Armati Ing. Mantelli 8
Societa Elettro-Morsetterie Volpato ... ... —
Societe Dauphincise d'Etudes & de Montages ... —
Societa Nazionale Delle Officine Di Savigliano ... —
Societe des Forges et Ateliers Du Creusot ... ... —
Standard Telephones & Cables Ltd. ... ... —
Steatite & Porcelain Products Ltd. 49
Sulzer Bros. (London) Ltd. ... ... —
Svenska Metallverken, A/B ... ... —

T

Tampella OY ... ... —
Technoexport 17
Tees Side Bridge & Engineering Works Ltd. ... ... —
Terni 9
Tokyo Shibaura Electric Co. Ltd. 18
Torno, Giuseppe & Co. 23
Tosi, Franco, S.p.A. ... ... —

V

Vereinigte Osterreichische Eisen- und Stahlwerke 58 & 59
Victor Products Ltd. ... ... —
Vevey Engineering Works Ltd. ... ... —
Voith, J. M., G.m.b.H. 51

W

Waagner Biro ... ... —
White, R. & Sons (Engineers) Ltd. ... ... —
Wood, Hugh & Co. Ltd. 4

Y

Yorkshire Electric Transformer Co. Ltd. ... ... —

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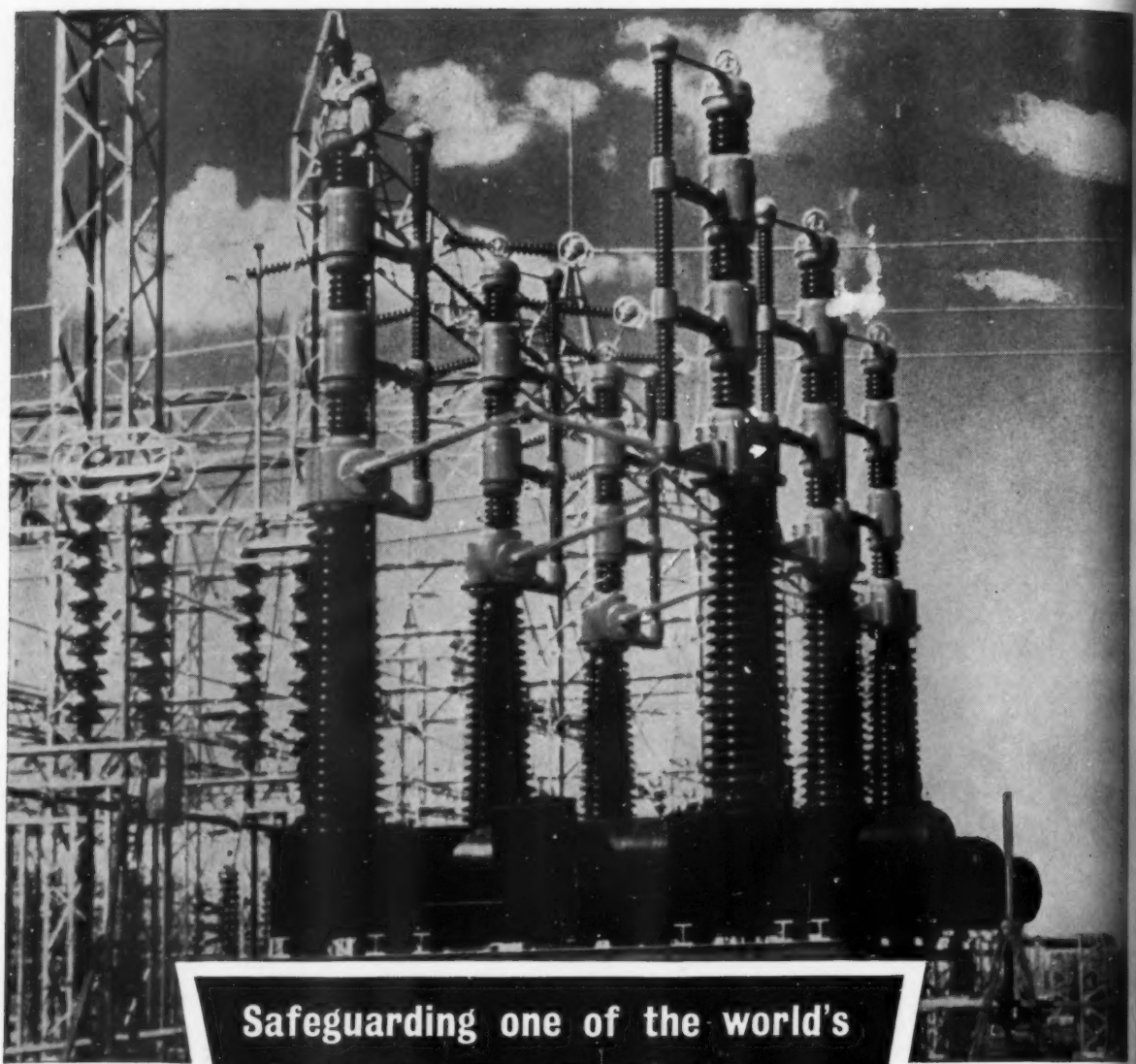

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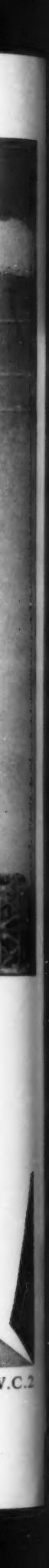
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